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QUANTITATIVE METHODS FOR EVALUATING THE QUALITY OF MACARONI PRODUCTS [1]

D. S. BINNINGTON, H. JOHANNSON, and W. F. GEDDES [2]

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The term "quality" as applied to macaroni products does not possess absolute significance and can only be defined on the basis of the factors contributing to consumer preference. The characteristics of a good macaroni have been defined by LeClerc (1933) as hardness, brittleness, translucency, elasticity, and a rich amber color. The fracture should be glassy and long pieces should be sufficiently pliable to allow of considerable bending before breakage. In addition, the behaviour upon cooking is most important; LeClerc states that when boiled for ten minutes, "a good macaroni will swell to at least twice its original size, will retain its tubular shape and its firmness, will not become pasty, and will have an agreeable odor." The factors associated with quality may thus be classified into three groups:

(1) Color and related factors such as vitreousness and translucency.
(2) Mechanical strength.
(3) Cooking characteristics, including water absorption, swelling, disintegration, and tenderness.

In a general way, the quality of macaroni may be assessed by means of visual examination and a simple cooking test, but such methods lack quantitative significance and are valueless when applied to the estimation of comparatively small differences. In the present paper, the development of quantitative methods is outlined and the interpretation of the values obtained is discussed.

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[2] Research Assistant, Associate Committee on Grain Research; Junior Chemist, Grain Research Laboratory, Board of Grain Commissioners for Canada; and Chief Chemist, Grain Research Laboratory, Board of Grain Commissioners for Canada, respectively.

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Color

In countries where the addition of artificial coloring matter is prohibited, color appears to be the principal basis of consumer preference and at the present time it is the most widely used quality index. The factors associated with a desirable macaroni color are quite complex, involving not only the pigment content but also translucency and vitreousness which, in turn, are apparently dependent upon the quantity and quality of the proteins and the degree of hydration of the starch. Wide variations in color can also be introduced by differences in processing technique as shown by Binnington and Geddes (1936). Accordingly, this quality factor cannot be adequately evaluated by any single analytical test, such as carotene or protein, and a direct determination is essential.

Measurement of macaroni color was first carried out in this laboratory by means of a spectrophotometer, employing discs cut from a flat strip produced by means of a special die. Material of this type is almost essential if a spectrophotometer is to be employed, and the method is therefore limited in its application. In addition, as indicated in an earlier study (Binnington and Geddes, 1936), the method is slow, the calculations involved are very laborious, and the results obtained are not readily interpreted in terms of visual color. In view of these limitations, the method was ultimately abandoned and attention directed to the use of a matching-type procedure, using the original-model Wallace and Tiernan colorimeter and discs as described by Baker, Parker, and Freese (1933) with a daylight lamp as illuminant. Later, a Bausch and Lomb Type H.S.B. Color Analyzer was secured, and the majority of color analyses conducted have been made with this instrument. Munsell discs have been used very largely, the following selection having been found to cover the majority of samples encountered:

Durum Semolina—Y — Y.R. 8/6, Y 8/12, N 9.4 and N 8.
Durum Macaroni and Spaghetti—Y.R. 6/12, Y 8/12, N 7 and N 4.

In expressing the results obtained with these discs, values for "hue," "brilliance," and "saturation" are computed according to the formula outlined by Nickerson (1929), and from these data an arbitrary single figure estimate of color has been derived as follows:

$$\text{Single-figure color score} = \frac{\text{hue}}{(\text{brilliance}/\text{saturation})}.$$

With varietal material, this arbitrary single-figure estimate of color has been found to yield results in excellent agreement with a careful visual classification; furthermore, it has been found possible to compare, directly, results obtained over a period of years.

In certain cases, particularly where graphical presentation is desired, Wallace and Tiernan color discs may be employed to decided advantage (Binnington and Geddes, 1937). However, such graphical expressions do not integrate the color constituents and it is necessary to accomplish such an integration in order to secure quantitative figures which will relate to visual appearance. For example, the arrangement of a series of samples on the basis of percentage of yellow alone will not correspond to a visual classification if the ratio of yellow to red varies, because the red component imparts a brownish characteristic to the color; similarly, the white and black components influence the visual appearance. Accordingly, an effort has been made to integrate the N. A. disc values into a single-figure color score. The initial step is to express the percentage readings of the four discs in terms of hue, saturation, and brilliance. This computation can be made from a knowledge of the Munsell equivalents of the N. A. discs but the calculation is exceedingly laborious and is otherwise unsatisfactory because of the wide separation in Munsell hue of the red and yellow N. A. discs. For these reasons it is deemed preferable to compute arbitrary indices of hue, saturation, and brilliance as follows:

$$\text{Hue} = \%\ \text{yellow}/\%\ \text{red}.$$
$$\text{Saturation} = (\%\ \text{yellow} + \%\ \text{red})/\%\ \text{black}.$$
$$\text{Brilliance} = \%\ \text{white} + \%\ \text{yellow}.$$

From the above values a single-figure estimate of color is computed by the arbitrary formula:

$$\text{Single-figure color score} = 2(\text{hue} \times 5 + \text{saturation} \times 2 + \text{brilliance}/4).$$

In this formula an attempt has been made to weight the various components according to their relative significance as regards visual appearance; it differs from that employed in computing a single-figure score from the Munsell disc data because the indices designated as "hue," "saturation," and "brilliance" are purely arbitrary and their magnitudes bear no relation to the corresponding values for the Munsell discs.

As the two systems of computing a single-figure color score are based on different data and employ different weightings, no direct comparison can be made between the scores which, in addition, are of quite different magnitudes. The Munsell disc method gives values on experimentally processed durum macaroni ranging from 12 to 25 units and has been found especially suited to studies involving varietal material; the N. A. disc procedure yields scores ranging from 50 to 100 units and appears better adapted to studies on samples where differences in hue are slight and saturation and brilliance are the principal factors responsible for color variations.

The actual color measurements are made upon a layer of the material of sufficient thickness to eliminate any "background" effect and with the Bausch and Lomb instrument the sample is not rotated.

Mechanical Strength

A high degree of mechanical strength is desirable in macaroni products in order to minimize breakage. As indices of mechanical strength, measurements of tensile strength, crushing strength, and transverse and torsional breaking strength might be carried out but, for macaroni products, a test of the transverse breaking strength appears the most suitable. Tensile-strength tests are not feasible because of the difficulty of clamping without breaking; crushing tests would require sensitive methods of measuring the small loads required for such fragile material, while torsional tests are only applicable to spaghetti or other products of similar diameter.

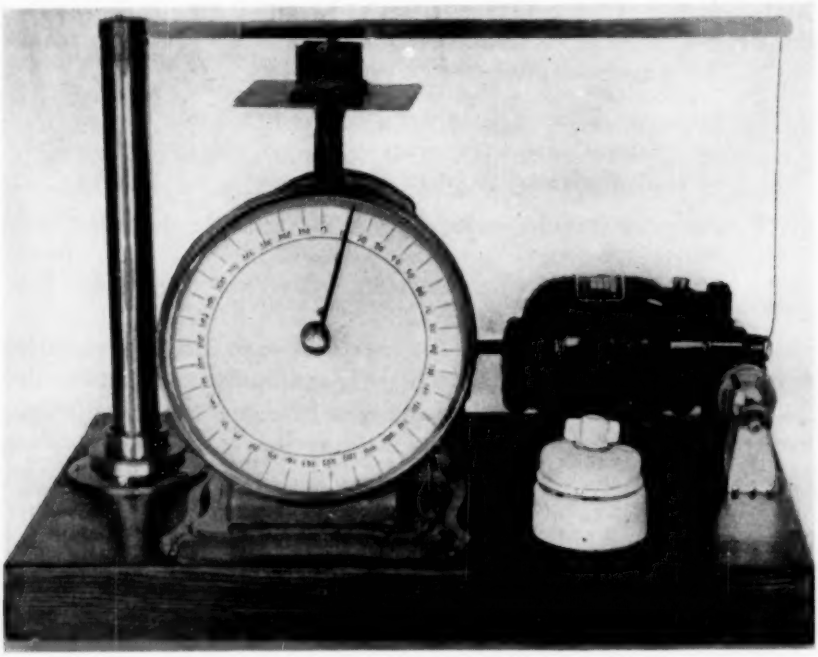

Fig. 1. Breaking-strength tester.

The breaking-strength apparatus employed is illustrated in Figure 1 and is modeled along the lines of the Bailey shortometer (1934). The sample is placed across two supports mounted on the pan of a 24-pound dial-indicating spring scale, the load being applied by means of a pivoted

bar driven through the medium of a cord and winch from a slow-speed (5 r.p.m.) motor; a non-return pointer is fitted to indicate the breaking point. The dial of the scale was replaced by one graduated in angular degrees and the results obtained have been recorded directly in these units.

The accuracy of the test was studied by means of 20 replicate tests conducted upon each of five replicate processings of macaroni. The results are summarized in Table I, and show that there is considerable

TABLE I

BREAKING STRENGTH OF MACARONI FROM FIVE REPLICATE PROCESSINGS

Batch No.	Mean breaking strength (20 readings) arbitrary units	Variance analysis				
		Variance due to:	D.F.	Variance	F.	5% pt.
1	152.3	Differences between batches	4	6348.46	19.70	2.46
2	151.0	Differences within batches	95	322.23	—	—
3	193.4	Total	99	565.71	—	—
4	174.8	Standard error of single observations = 23.78.				
5	175.4	Standard error of means of 20 readings = 5.32.				

variation between replicate tests made on the same batch and also that there is a significant difference between batches. Taking into consideration both the variation within and between batches, the above study gives a standard error for the means of 20 determinations of 5.32 units in breaking strength, which implies that the differences between the means of 20 tests for any two different macaronis must equal or exceed 16 units in order to be significant.

In view of the wide variation in the breaking strength of different portions of the same strand, an extensive series of tests was made in which breaking strength was compared with minimum and maximum wall thickness and diameter. A statistical analysis of the data, however, showed that differences in these dimensions were not the primary causes of variation in breaking strength. This result is rather surprising and suggests that the variations found are connected with the internal structure, as, in the case of such replicate tests, differences in composition are not involved. It was felt that some of the variations encountered might be due to some feature of the experimental press, such as irregularities in the dies or inadequate pressure. Measurement of the die

openings did not substantiate this hypothesis, and a limited number of tests made with high-grade commercial macaroni indicate that the variation is just as great with this class of material in spite of the fact that wall thickness and diameter are somewhat more uniform.

The relation between protein content and breaking strength was investigated with a series of macaroni samples processed from Canadian amber durum wheat of varying protein content and grade prepared by compositing a large number of envelope samples. The results presented in Table II indicate that breaking strength increases significantly with

TABLE II

RELATION BETWEEN PROTEIN CONTENT OF WHEAT AND BREAKING STRENGTH OF MACARONI

Nos. 1 and 2 C.W. Amber Durum		Nos. 3 and 4 C.W. Amber Durum	
Protein content (13.5% M.B.)	Mean breaking strength	Protein content (13.5% M.B.)	Mean breaking strength
%	*Units*	%	*Units*
10.6	153.0	10.7	162.5
11.4	166.2	11.5	167.2
12.4	169.5	12.2	177.0
13.3	190.4	13.1	178.8
14.0	196.8	14.2	185.0
		15.1	190.5
Mean	175.2		174.1

increasing protein content and also that the rate of increase is greater in the instance of the higher grades. When the method was applied to a wide range of varietal material, however, no simple correlation could be discerned between protein content and breaking strength, and it would appear that other factors possibly associated with protein quality are also effective.

Comparative breaking-strength studies have also been conducted on macaroni processed from semolina, farina, and flours of varying extraction prepared from single samples of durum and hard red spring wheat. The results given in Table III show an increase in breaking strength from semolina or farina to flour. The increase in protein content is undoubtedly a contributing factor to the trends observed but the large increase in breaking strength of macaroni processed from 50% patent durum flour, as compared with the semolina which is only 0.4% lower in protein content, indicates that granulation is an important factor.

The breaking strengths observed with experimentally processed material range from 140 units to 200 units, whereas commercially

TABLE III

BREAKING STRENGTH OF MACARONI PRODUCED FROM DURUM AND HARD RED SPRING WHEAT PRODUCTS

Basic material	Protein content (13.5% M.B.)	Macaroni breaking strength
	%	*Units*
Durum semolina	12.9	164
Durum flour 50% patent	13.3	182
Durum flour 60% patent	13.2	177
Durum flour 70% patent	13.8	180
Equal parts of semolina and 60% durum flour	—	166
Hard red spring farina	12.9	159
Hard red spring flour 50% patent	14.2	186
Hard red spring flour 60% patent	14.1	179
Hard red spring flour 70% patent	14.4	184

processed samples of similar diameter and wall thickness yield results in the order of 235 to 280 units. These differences suggest that factors involved in processing, such as pressure, etc., have an important influence upon the results and, unless the technique is carefully controlled, may easily mask differences due to composition.

Cooking Characteristics

The cooking properties of macaroni are highly important and may be roughly defined as the ability to resist disintegration upon prolonged boiling with water, coupled with a satisfactory degree of tenderness in the finished product. Quantitative measurement of such characteristics is a very difficult problem, and tests of this kind have been usually confined to a visual estimate of turbidity in the cooking water, coupled with mastication of the macaroni, as an index of tenderness. Early attempts to evaluate these qualities quantitatively by active boiling were unsuccessful; the amount of disintegration found was exceedingly variable and no method was available for measuring tenderness.

Recently, the Italian investigator Borasio (1935) has published a valuable paper on the cooking characteristics of alimentary pastes, and details methods he has developed for their investigation. His technique has served as a basis for the procedure to be described, and, as the original paper is not readily available, this work is reviewed in some detail. Borasio lists the principal characteristics of interest from a cooking standpoint as:

(1) Degree or amount of cooking required.
(2) Resistance to disintegration.
(3) Capacity for absorption of water.
(4) Increase in the volume of the paste.

A paste of good quality possesses a notable cooking degree (*i.e.*, requires a relatively long time to cook), a high degree of resistance to disintegration, a large water absorption, and a considerable increase in volume. He points out that cooking tests made by active boiling are subject to considerable variation due to concentration and violent agitation, and outlines a test in which 250 g. of macaroni is cooked, without boiling, in 1 liter of 1% salt solution by means of an oil bath maintained at 105° C. The time in minutes required for complete cooking is taken as a measure of the cooking quality. Unfortunately, however, no indication is given as to the criteria employed to judge when cooking is complete.

In addition to ascertaining the cooking time, the water absorption is determined by draining for five minutes on a Buchner funnel and observing the increase in weight. Volume increase is measured by placing the cooked and drained sample in a specially designed volumeter and adding a known amount of water; the increase in volume is read from a graduated tube, a similar determination having been conducted with the uncooked material. Resistance to disintegration is estimated in an approximate manner by allowing the residual water from cooking to stand in a graduated cylinder and measuring the volume of deposited material. More accurately, the residual water is made up to definite volume and an aliquot evaporated to dryness on a steam bath in a tared beaker and dried to constant weight at 105° C., the presence of added salt being corrected for by a quantitative determination of chlorine. It is stated that with macaroni of good quality, the residue will not exceed 6%.

Development of the test.—In developing a test along the lines of the above procedure, it was felt that some method of measuring tenderness was essential, and as a preliminary, a tenderness tester was constructed, modeled along the lines of the instrument designed by Bonney, Clifford, and Lepper (1931) for canned fruits and vegetables. This device consists essentially of a plunger terminating in a circular metal disc which rests upon the sample to which a load is applied at constant rate by means of mercury until a predetermined reduction in sample thickness is obtained; the weight of mercury is taken as an index of the tenderness.

The major factors associated with the test were investigated with a modified form of this apparatus, and the following conclusions drawn:

(1) It is necessary to take the mean of at least five replicate tests from a single cooking in order to secure a fair average.

(2) A definite optimum time of cooking appears to exist beyond which excessive softening results.

(3) Standing in water at room temperature for a moderate length

of time (30 minutes) after cooking does not affect the results appreciably.

(4) Small variations in macaroni temperature have no significant influence on the compression values.

(5) The presence of salt in the water employed for cooking results in increased tenderness for a similar cooking time. There is some indication, however, that the variability is increased.

The selection of a suitable thickness to which the sample should be compressed remained to be determined and, in an effort to investigate this, a test was made in which the load was applied in increments of 100 g., the reduction in thickness being measured after each addition. The results, calculated as percentage reduction in thickness and plotted against load, are show in Figure 2.

The initial rapid drop represents the collapsing of the tube walls under the weight of the plunger and flask; compression then proceeds at a uniform rate over a considerable load-range and then increases rather rapidly. Obviously, the latter corresponds to a definite "yield" or "break" point, at which the sample gives way completely. A very important point disclosed by these studies was the effect of rate of

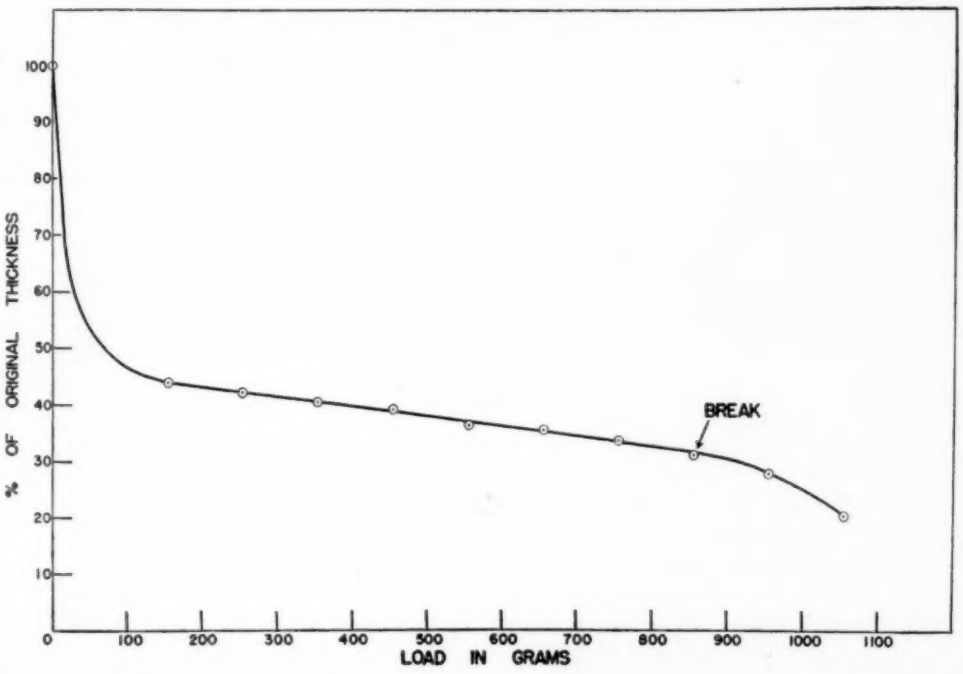

Fig. 2. Graph showing reduction in thickness of cooked macaroni with increasing load.

application of load, which must be quite uniform if comparable results are to be secured. This precluded routine application of the test in the manner described above and suggested the desirability of incorporating a recording device.

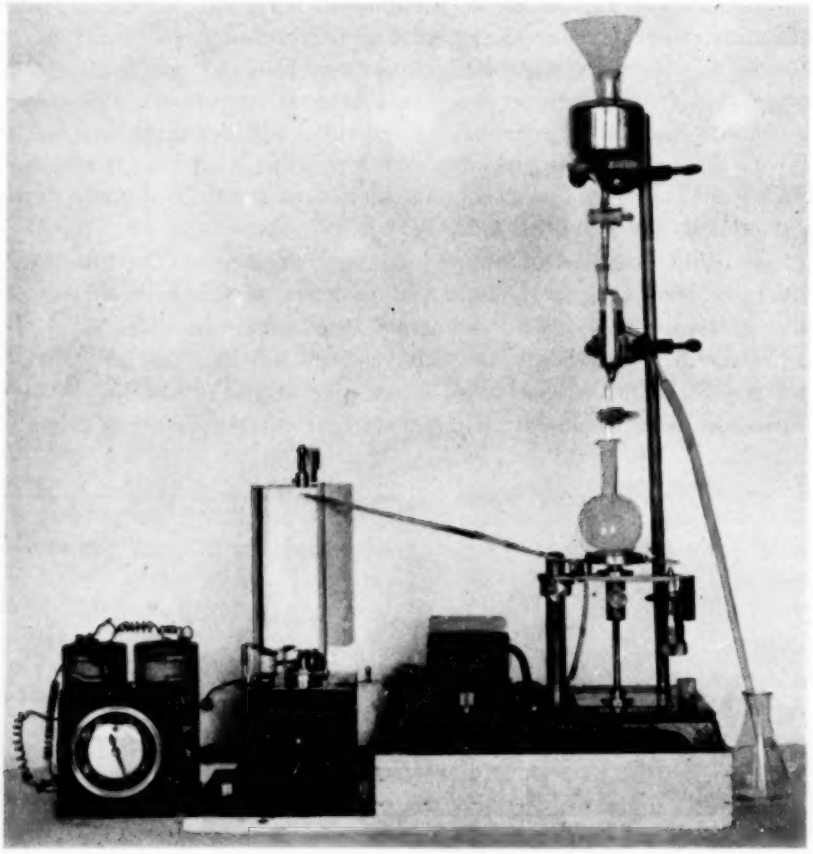

Fig. 3. Recording tenderness tester.

Description of recording tenderness tester.—The apparatus as finally developed is illustrated in Figure 3 and certain details in Figures 4 and 5. It consists essentially of a plunger terminating in a circular brass disc 30.5 mm. in diameter and fitted with a platform to hold a 125 ml. flask. The total weight of this assembly, including the flask, is approximately 160 g. Means are provided for loading with mercury at a constant rate, and the compression characteristics of the sample may be measured in terms of weight of mercury with the aid of a micrometer device, or a record may be obtained upon a slow-speed kymograph chart.

The main assembly is mounted on a stout pillar and is so located that the recording pen is approximately ¼ inch below the top of the chart when the disc is in contact with the base of the instrument. This position is designated as the zero point and corresponds to a micrometer

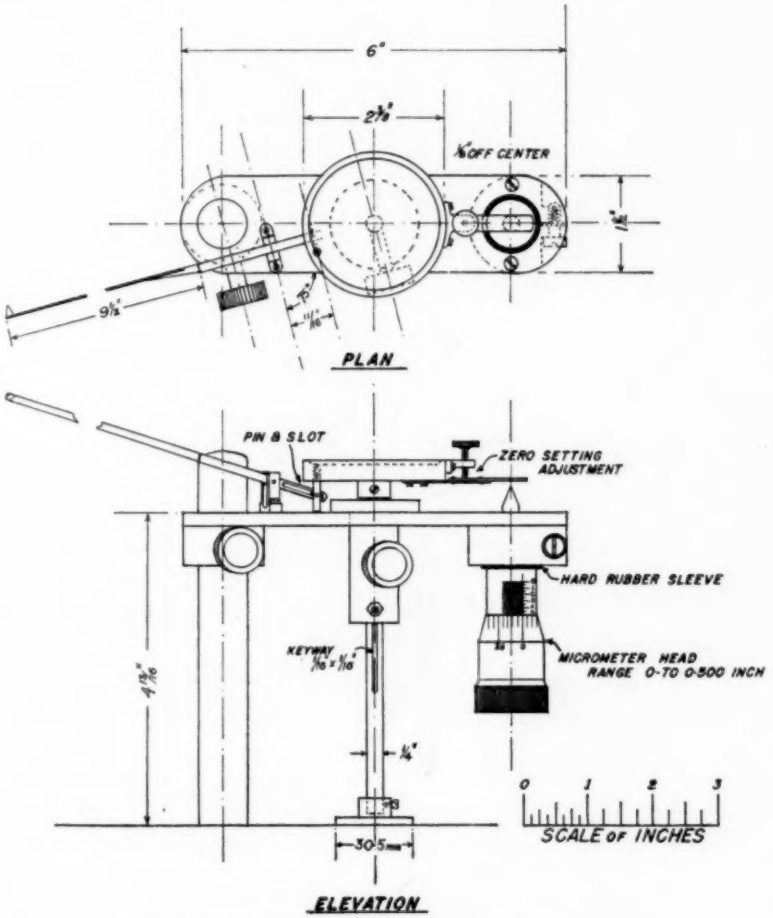

Fig. 4. Recording tenderness tester; detail of main assembly.

setting of .500 inch. The micrometer head is insulated from the remainder of the assembly, and an exact indication of the zero point is secured by means of an electrical contact between the micrometer spindle and a metal strip attached to the platform; this contact may be made to actuate a buzzer or signal light as desired. Setting of this zero is facilitated by mounting the contact strip on the end of a strip of spring bronze, which is raised or lowered by means of a fine thread

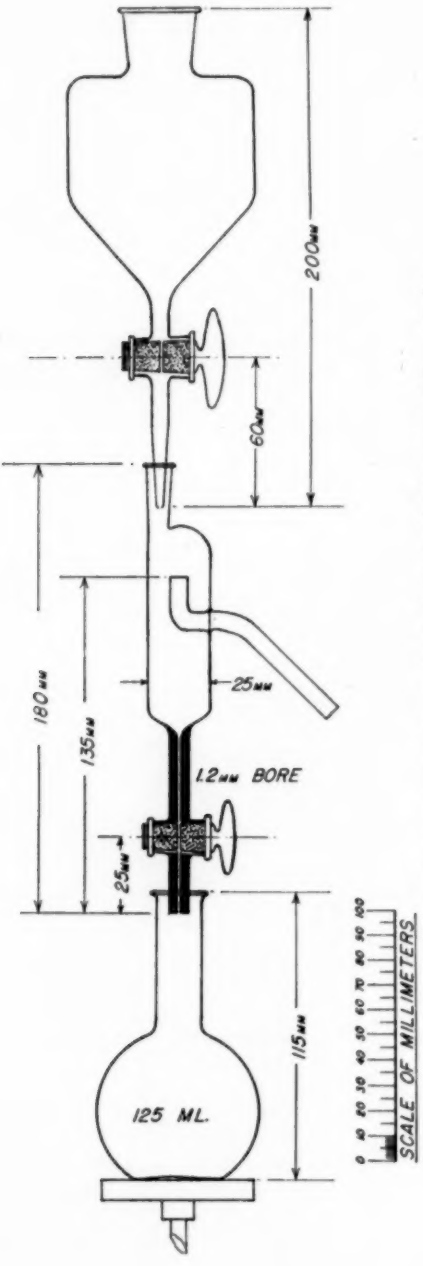

Fig. 5. Recording tenderness tester; detail of constant-head mercury delivery device.

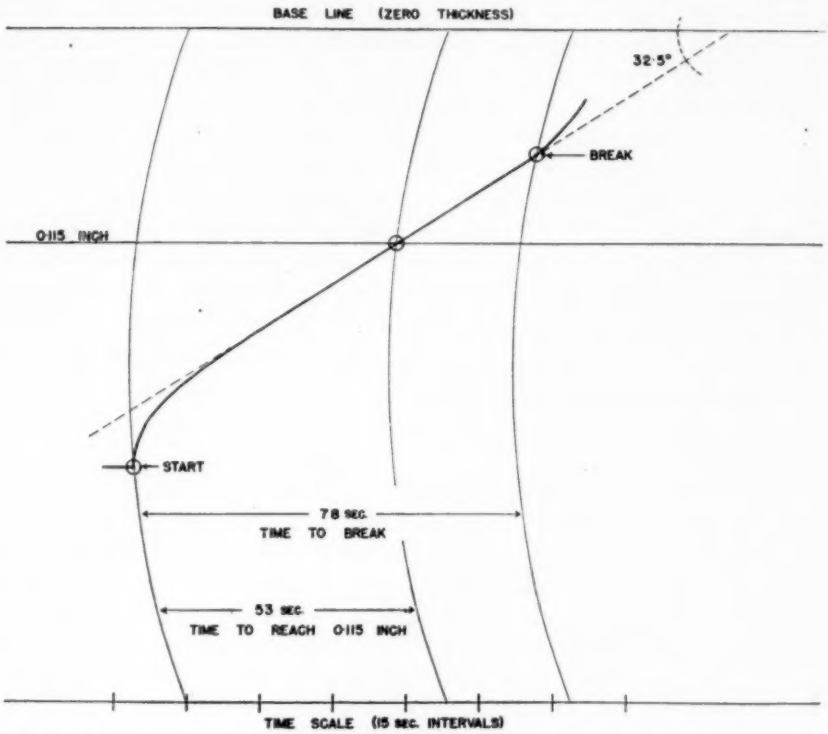

Fig. 6. Reproduction of tenderness test chart illustrating the measurements employed for evaluation.

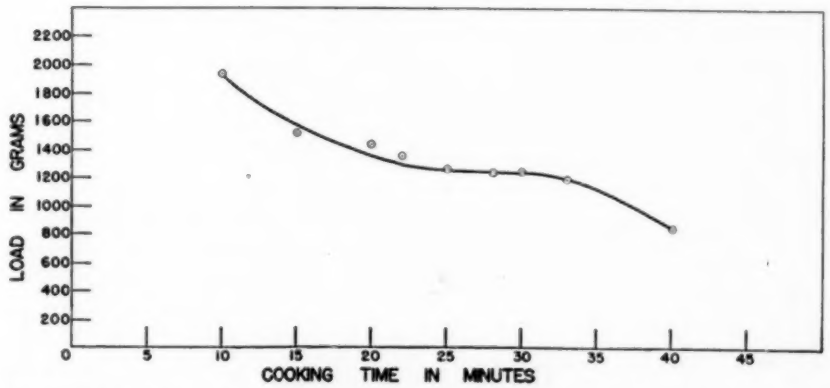

Fig. 7. Graph showing relation between cooking time and load required to compress the cooked macaroni to 25% of the original thickness.

screw. The micrometer device is employed to measure the original thickness of a sample and can then be set to indicate when compression has proceeded to a specified fraction of this amount; alternatively it may be used to establish a thickness scale upon the kymograph chart. This scale is then transferred to a strip of celluloid and used in measuring and interpreting charts obtained with the recording device.

For recording purposes, the vertical motion of the plunger is multiplied by means of a long lever arm coupled to the platform by means of the pin-and-slot device illustrated in Figure 4. When properly fitted, this system is practically free from backlash and permits of establishing a linear thickness scale upon the chart. In order to prevent turning of the platform with consequent disengagement of the pin from the slot, the plunger is key-way cut and a key fitted into the bearing. A lock-screw is also fitted enabling the system to be temporarily held in a raised position.

Recording is accomplished upon a kymograph drum 4 inches in diameter by 6¼ inches in height, rotating at a speed of one revolution in approximately 11 minutes. The drive is from the hour spindle of a spring-wound clock suitably geared up. Unless very carefully constructed with specially cut gears, such a system possesses considerable backlash, and a uniform time scale cannot be established. For this reason, the kymograph has been fitted with a time-marking device actuated from a modified Telechron clock marking every 15 seconds. A synchronous motor drive would undoubtedly be superior to the clock-work arrangement described and might eliminate the necessity of an independent time-marking system.

Load is applied to the sample at a constant rate of approximately 12 g. per second, by means of mercury delivered from the constant-head device illustrated in Figure 5. In this apparatus, mercury flows into the constant-level vessel at a rate slightly in excess of its delivery to the loading flask, the surplus overflowing into a receiver. With this arrangement the head may be maintained constant within 1 to 2 mm. The orifice of the delivery tube is adjusted to deliver 57 c.c. per minute. Clean, redistilled mercury is employed and the delivery rate checked frequently, as it tends to slow down with time due to surface oxidation. When it has fallen to 55 c.c. per minute, the mercury is removed and cleansed by spraying through dilute nitric acid; the apparatus is also cleaned with the same solvent.

A typical record obtained with the tenderness tester is illustrated in Figure 6, together with details of the various characteristics of the curves that have been found most valuable in recording and interpreting the results. The best single index appears to be the time from the start of application of load to the break point. (This value can be expressed

as actual load, because the rate of application is constant; in view of the magnitude of the internal variability, however, no useful purpose could be served by such twelve-fold increase in these values.) The second value recorded is the time required to compress the sample to an arbitrary thickness of 0.115 inch. This point was selected because in the majority of cases it falls in the linear portion of the record and definitely below the break-point. The third value employed is the angle made between a prolongation of the linear portion of the curve and the so-called base line. A fourth value is secured by computing the ratio of "time to reach 0.115 inch" to "time to break." From these values a single-figure tenderness score is tentatively computed by the following formula:

$$\text{Tenderness score} = \text{time to break} + \text{angle} + (\text{ratio} \times 10).$$

Details of cooking testing procedure.—A high-temperature thermostat is employed for the actual cooking and is so adjusted that the water temperature in the beakers falls between 95.5° and 96.0° C. If oil is employed in the bath, a temperature of 105° to 106° C. is required; if, however, ethylene glycol (commercial Prestone) is used, a temperature of only 101.0° to 101.5° C. is required. A 500-c.c. tall-form lipless beaker is placed in the bath and 250 c.c. of distilled water, previously heated to approximately 95° C., is added. The beaker is covered with a watch glass and allowed to remain until the temperature reaches 95.5° to 96.0° C. A 25-g. sample of macaroni is introduced and thoroughly stirred. Cooking is continued for exactly 30 minutes, with stirring at 10-minute intervals. The beaker is then removed from the bath and the macaroni drained in a tared basket for two minutes, weighed, transferred to a beaker, and washed three times with cold tap water.

The sample is stored under tap water until required for the tenderness measurements which are made upon five strands selected at random, drained and placed on filter paper before locating under the plunger of the apparatus.

The additional values detailed by Borasio (1935) are outlined below.

Volume of dry macaroni.—This determination is conducted with a 10-g. sample and a small volumeter consisting of a 50-c.c. Erlenmeyer flask fitted with a ground-glass joint and a measuring tube graduated from 0 to 10 c.c. in 1/20 c.c. High-boiling petroleum naphtha is employed as the displacing liquid since water might introduce appreciable errors due to swelling during the determination. Borasio used water and apparently determined the dry volume on the cooking test sample; in our experience this prior wetting introduces serious irregularities into the tenderness results.

Water absorption.—This value is computed from the increase in weight upon cooking as outlined above.

Volume increase with cooking.—Originally, the measurement of wet volume was conducted according to the procedure outlined by Borasio, with a specially built volumeter. Examination of a large number of results, however, indicated that a very close relation existed between wet weight and volume, and statistical analysis of these data showed a correlation of .984, a value sufficiently high to permit of accurate prediction of the latter from the former by the following formula:

$$\text{Volume of cooked macaroni} = -8.81 + 1.0085 \times \text{net weight.}$$

The volume increase may be obtained by relating the wet volume to the dry volume; this latter value, however, has been found to vary only within a very narrow range, and for this reason it seemed unnecessary to carry this phase of the testing beyond the determination of water absorption.

Residue.—The drainings from the cooked sample are cooled and made up to 200 c.c. A 50-c.c. aliquot is transferred to a weighed 100-c.c. beaker evaporated to dryness on the steam bath and dried in a 130° C. air oven for 1 hour. If the presence of added salt is indicated, a correction must be made by ashing an aliquot of the residue and determining the chlorine content.

Notes on the test.—In the above description of the testing procedure, a cooking time of 30 minutes is specified; selection of this time was based on the cooking-curve data obtained in the preliminary studies. A typical curve of this kind is illustrated in Figure 7 and indicates the existence of an optimum tenderness region falling between 25 and 30 minutes of cooking. With 22½ minutes or less, the material would appear to be definitely on the "tough" side, and beyond 32½ minutes an irregular tendency towards excessive softness is noted. The existence of such a flat region in the cooking curve was confirmed by tests conducted at a later date, employing the recording instrument; data from a study of this type are presented in Table IV. It is of interest to note, however, that while the tenderness score indicates a leveling out in the 25- to 30-minute region, absorption and disintegration proceed at a fairly uniform rate throughout the whole period. As yet, insufficient results are available to state definitely whether or not this optimum cooking time varies greatly from sample to sample; the general trend of the evidence so far accumulated, however, indicates that for the majority of samples it falls between 25 and 30 minutes and a 30-minute cooking time has been employed in all our studies to date.

The effects of added salt represent an additional complication. As

TABLE IV

EFFECT OF TIME OF COOKING UPON TENDERNESS SCORE, ABSORPTION, AND DISINTEGRATION

Time of cooking	"A" Time to break	"B" Time to reach 0.115 inch	Ratio "A" to "B"	Angle	Single figure tenderness score	Absorption	Residue
Min.	*Sec.*	*Sec.*		*Deg.*		%	%
20.0	98	48	2.02	24.8	143.0	256	4.27
22.5	94	62	1.51	24.6	133.7	284	4.60
25.0	87	59	1.47	26.3	128.0	300	4.64
27.5	82	55	1.49	27.5	124.4	320	4.90
30.0	82	49	1.67	28.6	127.3	344	5.35
32.5	66	47	1.40	31.0	111.0	360	5.31
35.0	64	52	1.23	32.2	108.5	364	5.24
37.5	57	45	1.26	34.6	104.2	380	5.38
40.0	60	47	1.27	37.3	110.0	416	5.66

mentioned earlier, this was found to exert a marked softening effect, and data illustrating this are presented in Table V. In view of the fact that any reduction in tenderness might tend to minimize the spreads between samples, and also of the absence of salt in experimentally processed macaroni, the cooking tests have been conducted with dis-

TABLE V

EFFECT OF ADDITIONS OF SODIUM CHLORIDE UPON THE COOKING CHARACTERISTICS OF MACARONI

(Constant cooking time of 30 minutes)

Concentration of NaCl in cooking water	"A" Time to break	"B" Time to reach 0.115 inch	Ratio "A" to "B"	Angle	Single figure tenderness score	Absorption
%	*Sec.*	*Sec.*		*Deg.*		%
0.0	63	31	2.03	42.3	125.6	308
0.2	57	28	2.04	41.7	119.1	316
0.4	57	30	1.90	37.9	113.9	320
0.6	47	33	1.42	43.3	104.5	322
0.8	40	32	1.25	38.7	91.2	328
1.0	40	27	1.48	40.5	95.3	332

tilled water. Owing to the presence of varying quantities of added salt in commercial macaroni, the comparative tenderness scores would not necessarily indicate the relative inherent cooking properties of the pastes themselves; with this class of material it might be desirable to cook in a sufficiently high salt concentration to minimize the effect of variable salt content in the macaroni.

The replicability of the tenderness measurements between cookings is in the order of 4 to 8 units of tenderness score. The method has been applied successfully to a number of problems under investigation in this laboratory, however, and within several hundred tests upon macaroni processed from durum semolina the following range of values has been observed:

	Minimum	Maximum
Tenderness score	85.2	186.5
"Dry" volume, c.c. per 100 g. macaroni	69.6	73.2
Absorption, %	264.0	328.0
Wet volume, c.c. (computed) per 100 g. "dry" macaroni	358.3	432.8
Volume increase on cooking, times original volume	5.14	6.00
Residue, %	4.64	7.16

On the basis of these tests, a tentative scale of tenderness score values has been worked out as follows:

Soft	Tenderness score below 100
Slightly soft	Tenderness score 100–114
Normal	Tenderness score 115–129
Slightly tough	Tenderness score 130–144
Tough	Tenderness score 145–159
Very tough	Tenderness score over 160

It is very probable that the "slightly soft" and "slightly tough" groups fall in the category of satisfactory commercial tenderness, but more extensive studies, particularly with a wider range of commercial samples, are required before definite limits can be postulated.

Discussion

In the work reported, the principal object has been the development of methods and apparatus for the quantitative measurement of the factors associated with macaroni quality. These factors have been classified into three major groups, namely color, mechanical strength, and cooking characteristics. Color measurement has been dealt with rather briefly, as the methods are fairly well known and the further extension of this phase of macaroni testing awaits the development of more suitable color-analyzing equipment. In connection with the cooking tests, all the data obtained so far have been for a single size of macaroni [3] and any departure from this class of material would undoubtedly affect the results. This criticism does not invalidate the utility of the method, however, and it is entirely possible that some means may be devised for relating the results obtained with different classes of material.

[3] Die 3/16" diameter, 1/16" aperture.

Summary

The term "quality" as applied to macaroni products is discussed and the factors associated with desirable commercial characteristics are detailed.

Various methods of measuring color are described, suitable Munsell discs for matching macaroni products are listed, and formulae for calculating single-figure color scores from both Munsell and Wallace and Tiernan disc results are presented.

An instrument for measuring transverse breaking strength is described. The variability of the test is rather high; this appears to be associated more with variations in internal structure than with differences in wall thickness and diameter. The breaking strength of commercial macaroni is substantially greater than that of experimentally processed material of similar size, indicating that breaking strength is influenced by processing conditions. A relation between protein content and breaking strength is indicated but where varietal comparisons are involved, variations in other factors, probably associated with protein quality, obscure this relation.

The development of a standard cooking test is outlined, a recording instrument for measuring the tenderness of the cooked macaroni described, and a method for computing a tenderness score presented. The accuracy of the test is in the order of 4 to 8 units of tenderness score and a range of from approximately 85 to 186 units has been found for macaroni processed from durum semolina. Cooking in the presence of salt produces a pronounced softening effect.

Methods for determining dry volume, water absorption, increase in volume, and extent of disintegration upon cooking are also detailed.

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THE WHEAT-MEAL-TIME-FERMENTATION TEST. II. EFFECT OF PROTEASES, PROTEASE ACTIVATORS, AND PROTEASE INHIBITORS [1]

C. O. SWANSON and F. T. DINES [2]

Kansas Agricultural Experiment Station, Manhattan, Kansas [3]

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In a previous paper [4] it was shown that the results in the wheat-meal-time-fermentation test are materially affected by fineness of grinding, length of storage after grinding, addition of ground bran or shorts, pumice stone, N-caproic and pelargonic acids, and by carbon dioxide dissolved in the water on which the doughball floats. Lecithin, oleic acid, paper pulp, and alundum had little effect on "time" [5] and no consistent effects were obtained from the use of $KBrO_3$ and $KClO_3$.

It is not a simple matter to evaluate the "time" test as a quality measure. Spring wheats as a rule have a long "time," most hard winter wheats have a medium "time," a few have a long "time," and soft wheats as a rule have a short "time." Thus within certain limits it may be said that the test will differentiate varieties as strong, medium, and weak, using these terms not as indicating superiority or inferiority, but rather as adaptation for certain types of baking. One of the chief merits of the test is the small sample required and the comparative simplicity of the apparatus. This has made it most useful to plant breeders as it enables them to differentiate among hybrids and selections much earlier in their program than is possible with tests requiring larger amounts of grain. Although the relationship of "time" to baking results and other estimates of quality has not been clearly shown, there seems to be little doubt that it is a varietal quality factor particularly in the instance of crosses between long "time" and short "time" parents.

The method of mixing the meal, the technique of handling the doughballs, and the importance of the temperature control were discussed in the previous paper. Further experiments have shown that for grinding to pass a ½-mm. sieve a small Jacobson hammer mill was more satisfactory than a burr mill. This hammer mill grinds more rapidly than the well known Wiley mill and is much more convenient to clean between samples. Since the particles pass the screen as soon as they have

[1] Much of the data in this paper is taken from a thesis presented to the graduate faculty of Kansas State College by Mr. F. T. Dines in partial fulfillment of the degree of Master of Science.

[2] Head of Department of Milling Industry and Research Assistant in Agronomy.

[3] Contribution No. 57, Department of Milling Industry.

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[5] "Time" in this paper means the minutes from the moment the doughball was placed in the water until disintegration is observed on its underside while floating, and hence is used instead of the longer name for this test.

come to the required degree of fineness and cannot get away from the action of the hammers until this condition exists, a meal of fairly uniform granulation is produced. That the mechanical impact on the kernels from hard wheat would produce meal somewhat different in characteristics from the soft-wheat meal is no doubt true, but, as far as known, this in itself does not significantly influence the "time."

The technique of the test lends itself to the investigation of several problems. One of the most important of these has to do with the factors which influence the "time" and the present study was directed toward a partial solution of that problem. It had been observed that the time was influenced by proteases and their inhibitors. For this study it was desirable to use a normally long "time" wheat in comparison with a normally short "time" wheat. Tenmarq, a hard winter wheat, was used to represent the former and Clarkan, a soft winter wheat, the latter. Averages of a large number of determinations made on the meals, were 114 minutes for Tenmarq "time" and 40 minutes for Clarkan "time." Hence these two wheats were well adapted for this study because they give a wide range in "time" and they are also very different in other quality characteristics. Tests were also made on a number of other varieties and crosses as will appear in the tables which follow.

The proteases tried were pepsin, trypsin, and papain. The activator used was anhydrous cysteine-monohydrochloride. The inhibitors were potassium bromate and ascorbic acid, also known as cebione. These substances were usually added in water solutions by means of a syringe to the meal or flour while being mixed in the small mixer. The amounts given in the various tables represent what was added to the 15 g. of meal or flour.

Effect of the Amount of Pepsin on the "Time" of Tenmarq and Clarkan

The data in Table I show the effects of different amounts of pepsin added to the meals of Tenmarq and Clarkan. The decreases in minutes due to pepsin are very small for Clarkan in amounts greater than 1.0 mg. and for lesser amounts the results indicate no consistent effect. For Tenmarq progressively greater decreases occur in "time" with increasing amounts of pepsin from 0.1 mg. to 1.5 mg. Larger dosages of pepsin do not give any significantly greater effect. The data indicate that 2 mg. of pepsin produces about the maximum effects; hence this amount was used in most of the subsequent work with the proteases.

It is evident that the behavior of Tenmarq is very different from that of Clarkan. The latter variety appears to be almost insensitive to

TABLE I

EFFECTS OF VARYING AMOUNTS OF PEPSIN ON THE "TIME" OF TENMARQ AND CLARKAN

Pepsin added	Tenmarq		Clarkan	
	Total	Decrease	Total	Decrease
Mg.	*Min.*	*Min.*	*Min.*	*Min.*
None (Av. 2 checks)	123	—	45	—
0.1	118	5	47	+2
0.2	108	15	45	0
0.3	103	20	54	+9
0.4	87	36	47	+2
0.5	82	41	41	4
1.0	69	54	46	+1
1.25	61	62	43	2
1.50	53	70	43	2
1.75	55	72	43	2
2.00	51	76	40	5
2.25	46	81	45	5
2.50	49	78	41	4

pepsin, while Tenmarq seems to be very sensitive because it drops very rapidly from a long initial "time" to almost as short a "time" as Clarkan. The decreasing magnitude in the amount of change for Tenmarq with the larger amounts of pepsin suggests that there is an irreducible minimum time below which not much reduction can be expected from the action of the protease. This appears to be similar to the limits in the reduction of loaf volume.

Results with Trypsin and Papain

Trypsin and papain were tried in the same manner as pepsin and the results obtained with the various amounts are given in Table II.

There seems to be very little difference in effectiveness of trypsin and papain in decreasing the "time" of Tenmarq and for amounts larger than 1.0 mg. they compare closely to pepsin. For small amounts

TABLE II

EFFECTS OF VARYING AMOUNTS OF TRYPSIN AND PAPAIN ON THE "TIME" OF TENMARQ AND CLARKAN

Amount added	Tenmarq				Clarkan			
	Trypsin		Papain		Trypsin		Papain	
	Total	Decrease	Total	Decrease	Total	Decrease	Total	Decrease
Mg.	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*	*Min.*
None	108	—	108	—	37	—	37	—
0.5	58	50	65	43	35	2	37	0
1.0	38	70	35	73	36	1	37	0
1.5	39	69	37	71	35	2	32	3
2.0	40	68	33	75	37	0	30	7
2.5	36	72	30	68	36	1	30	7

such as 0.5 mg. and 1.0 mg. these two proteases produce greater decreases than pepsin. The effect on Clarkan was negligible for trypsin and very small for papain. Since there seemed to be no particular advantage in either trypsin or papain over pepsin in this investigation the latter was generally used.

Effect of Pepsin on the "Time" of Hard, Semihard, and Soft Wheats

The large decrease in "time" due to the effect of pepsin on the hard wheat Tenmarq, as compared with the small effect on the soft wheat Clarkan, suggested the use of this protease on a number of hard, semihard, and soft-wheat varieties with 2 mg. for each 15 g. of meal. The data obtained are given in Table III.

TABLE III

EFFECT OF PEPSIN ON THE "TIME" OF HARD, SEMIHARD AND SOFT WHEATS

Variety	Treatment		
	No pepsin	2 mg. pepsin	Decrease
	Min.	*Min.*	*Min.*
Hard wheats			
Oro x Tenmarq, Ks. 2729	130	65	65
Oro x Tenmarq, Ks. 2728	128	60	68
Oro	126	43	83
Tenmarq, Ks. 514	105	44	61
Cheyenne	94	42	52
Cheyenne sel., C.I. 11666	91	44	47
Turkey sel., C.I. 10094	90	53	37
Kanhull	88	42	46
Quivira	66	34	32
Kanred	51	39	12
Blackhull	51	39	12
Early Blackhull	47	37	10
Turkey	40	29	11
Chiefkan	37	30	7
Superhard	33	26	7
Semihard wheats			
Denton	108	49	59
Minturki	84	44	40
Kawvale	46	33	13
Iobred	41	31	10
Soft wheats			
Clarkan	39	37	2
Bald Rock	38	39	1+
Mo. Early Premium	33	32	1
Michigan Amber	33	34	1+
Harvest Queen	32	32	0
Red Rock	30	30	0
Mediterranean sel. C.I. 11567	30	28	2
Fulcaster	29	26	3
Currell	27	27	0
Michigan Wonder	27	28	1+

The variations in the data for the soft wheats are within the experimental error and hence it appears that pepsin produces no definite decrease. The hard wheats show a very large variation in the effect of pepsin in decreasing the time. Some hard wheats were affected comparatively little. As a rule the shorter the time of the hard wheats the less the effect of pepsin. This same statement may also be made for the semihard wheats. The implication of this is that on wheats which have a short "time," whether hard or soft, the effect of pepsin will be slight, and that on the hard wheats the decrease due to pepsin will be greater on long "time" than on short "time" wheats. Thus the nearer the "time" of the wheat is to the irreducible limit, the less the reduction possible with the use of a protease.

The "time" was determined on a series of flours milled from samples grown in the wheat-breeding nursery. The results are given in Table IV. The "time" on flours has been found as a rule to be

TABLE IV

EFFECT OF PEPSIN ON THE "TIME" OF FLOUR FROM HYBRID WHEATS

Variety	Treatment		
	No pepsin	2 mg. pepsin	Decrease
	Min.	*Min.*	*Min.*
Oro x Tenmarq Ks. 2736	220	121	99
Fulhard x Kawvale, Ks. sel. 344154	197	127	70
Tenmarq Ks. 514	189	142	47
Oro x Tenmarq, Ks. sel. 343273	179	123	56
Kanred x Hard Federation, Ks. sel. 316063	175	121	54
Early Blackhull x Tenmarq, Ks. 2739	170	123	47
Oro x Tenmarq, Ks. sel. 363595	158	117	41
Oro x Tenmarq, Ks. sel. 363594	155	95	60
Oro x Tenmarq, Ks. sel. 363602	154	116	38
Oro x Tenmarq, Ks. 2730	142	115	27
Oro x Tenmarq, Ks. sel. 343638	139	110	29
Kanred x Kawvale, Ks. sel. J34584	139	113	26
Kanred x Marquis, Ks. sel. 285116	138	99	39
Oro x Tenmarq, Ks. sel. 343249	135	122	13
Tenmarq x Kawvale, Ks. sel. 33FN499	131	104	27
Kanred x Marquis, Ks. sel. 326795	127	100	27
Iobred x Kawvale, La. 35–95	127	83	44
Tenmarq x Kawvale, Ks. 2735	123	102	21

considerably longer than on meal. The decreases in "time" show considerable variation among the flours similar to that on the meals given in Table III. Direct comparisons cannot be made of the data in Tables III and IV because the meals and the flours were not from the same wheats.

Effect of Protease Activators

If the short "time" on Clarkan is due to an active protease, and if the long time on Tenmarq is due to the inactivity of the protease, the "time" on Tenmarq should be considerably shortened by a protease activator while the same activator would have little effect on Clarkan. The data in Table V bear out this supposition. The protease activator has a definite effect in decreasing the time on Tenmarq, but the magnitude of the decrease is less than with pepsin (Table I). On Clarkan the effect on "time" was probably not significant. It is very evident that the activator affects these two wheats very differently. If the averages of the checks, 114 for Tenmarq and 40 for Clarkan, were used for comparison, the data would show still larger differences between these two wheats. There is then an indication that the long "time" on Tenmarq has some connection with an inactive protease, since the presence of an activator does shorten the "time" but on Clarkan, in which the protease is apparently already active, the activator has little effect.

TABLE V

EFFECT OF A PROTEASE ACTIVATOR

	Tenmarq		Clarkan	
Cysteine	Total	Decrease	Total	Decrease
Mg.	*Min.*	*Min.*	*Min.*	*Min.*
None	110	—	36	—
0.5	107	3	43	7+
1.0	100	10	39	3+
1.5	76	34	42	6+
2.0	64	46	36	0
2.5	55	55	43	7+

Combined Effects of a Protease and an Activator

The cysteine-monohydrochloride was used in gradually increasing amounts on Tenmarq and Clarkan with 0.5 mg. papain. The results obtained are given in Table VI.

It is very evident that the 0.5 mg. papain used in connection with the cysteine produced distinctly larger effects than the cysteine alone or even pepsin alone (Table II). This may be significant with Clarkan, in which the activator alone produced small increase in "time" (Table V), but in combination with the papain the decrease is small.

Papain alone (0.5 mg.) produced no greater effect on Tenmarq than 0.5 mg. pepsin, but 0.5 mg. papain in combination with 2.0 mg. pepsin decreased the "time" to 35 minutes, whereas 2.0 mg. papain

TABLE VI

EFFECTS OF PAPAIN AND CYSTEINE

Amounts used		Tenmarq		Clarkan	
Papain	Cysteine	Total	Decrease	Total	Decrease
Mg.	*Mg.*	*Min.*	*Min.*	*Min.*	*Min.*
0.0	0.0	115	—	40	—
0.5	0.0	70	45	40	0
0.5	0.5	62	53	41	+1
0.5	1.0	58	57	41	+1
0.5	1.5	45	70	33	7
0.5	2.0	35	80	34	6
0.5	2.5	40	75	34	6
0.5	3.0	34	80	34	6

decreased the "time" only to 51 minutes (Table I). Thus the activator in combination with the protease produced greater decreases than when the protease was used alone. With 0.5 mg. papain plus 2.0 mg. activator the "time" on the two wheats was the same. This raises the question whether the differences in "time" obtained on varieties are due to variation in quality of proteins or to the state of the protease activity.

Effects of Inhibitors

If the "time" is shortened by proteases and protease activators, then it should be lengthened by protease inhibitors. The inhibitors tried were potassium bromate and ascorbic acid (cebione). The effects of the bromate are given in Table VII and of cebione in Table VIII.

TABLE VII

EFFECTS OF $KBrO_3$ ON "TIME"

$KBrO_3$ used	Tenmarq		Clarkan	
	Total	Increase	Total	Increase
Mg.	*Min.*	*Min.*	*Min.*	*Min.*
None	106	—	36	—
0.25	141	35	40	4
0.50	155	49	43	7
0.75	188	82	46	10
1.00	222	116	49	13
1.25	223	117	55	19
1.50	247	141	52	16
1.75	244	138	52	16
2.00	233	127	48	12
2.25	277	171	55	19
2.50	250	144	50	14
2.75	279	173	54	18

TABLE VIII

EFFECTS OF CEBIONE ON "TIME"

Cebione used	Tenmarq		Clarkan	
	Total	Increase	Total	Increase
Mg.	*Min.*	*Min.*	*Min.*	*Min.*
None	108	—	37	—
1.0	200+	92+	120	83
2.0	200+	92+	131	94
3.0	200+	92+	143	106

It is very evident that $KBrO_3$ increases the "time" on both wheats but much more on Tenmarq than on Clarkan. The "time" for Tenmarq was increased 2.6 times the check while the "time" for Clarkan was 1.5 times the check. However the increments of the increases cease to be definite at 1.5 mg. for Tenmarq and 1.0 mg. for Clarkan. That is, beyond about 240 minutes for Tenmarq and about 50 minutes for Clarkan further fluctuations cease to have any meaning. This indicates there is a limit for maximum effects as well as for the minimum "time" already pointed out.

The cebione produced a much larger increase on Clarkan than did $KBrO_3$. The increase on Tenmarq was also large, but it was not possible to get a good endpoint, hence the time was marked simply 200 + and this was obtained with the 1.0 mg. of cebione, which compares in magnitude with the effect of 1.0 mg. of $KBrO_3$. The fact that one milligram of the protease inhibitor, ascorbic acid, makes the "time" on Clarkan as long as that of Tenmarq, points to the probability that the short time on Clarkan is due to the presence of an active protease.

Effect of $KBrO_3$ and Pepsin

Pepsin was used alone and together with $KBrO_3$ on Tenmarq and Clarkan. The results obtained are given in Table IX.

TABLE IX

EFFECTS OF PEPSIN AND $KBrO_3$

	Tenmarq		Clarkan	
	Total	Change	Total	Change
	Min.	*Min.*	*Min.*	*Min.*
None	106	—	36	—
2 mg. pepsin	42	−64	40	+ 4
2 mg. $KBrO_3$	200+	+94	48	+12
2 mg. pepsin + 2 mg. $KBrO_3$	70	−36	49	+13

The four minutes' increase in Clarkan from 2 mg. of pepsin is within experimental error. The increase in "time" from 2 mg. of $KBrO_3$ is very large on Tenmarq in comparison with the small increase on Clarkan. The reason for this is not apparent. The $KBrO_3$ only partially inhibited the action of pepsin on Tenmarq. As was shown in Table I, pepsin had no effect on Clarkan; hence the combination of $KBrO_3$ with pepsin would show the effect of only the former.

TABLE X

EFFECT OF PEPSIN AND $KBrO_3$ ON SPRING WHEATS

Variety	No pepsin	2 mg. pepsin	Decrease	2 mg. $KBrO_3$
	Min.	*Min.*	*Min.*	*Min.*
Garnet	228	145	83	250+
Apex	172	108	64	250+
Reward	171	105	66	250+
Thatcher	139	79	60	250+
Marquis	134	87	47	250+
Ceres	126	77	49	250+
Renown sel.	104	73	31	248+

Pepsin and $KBrO_3$ were also tried on some additional spring wheats. The results obtained are given in Table X. The spring wheats behave in a manner similar to that of winter wheats in regard to the effect of pepsin. Those which have a long "time" show a greater decrease from the use of pepsin than those which have short "time." The proportional decrease, however, is about the same for both the long "time" and the short "time" wheats. The $KBrO_3$ has a decided inhibiting effect on all the varieties, so much so that only on one was the exact time obtained.

Summary and Discussion

The data presented in this paper show the following:

Pepsin decreases the "time" of Tenmarq to less than one-half that required without this protease. On Clarkan, a normally short "time" wheat, the effect is practically nil. Trypsin and papain in a limited trial had essentially the same effects as pepsin.

On a series of soft wheats whose "time" is normally short, there was no effect of pepsin. On a series of hard and semihard wheats the reduction in "time" due to pepsin was proportional to the length of "time" for untreated samples. That is, on the long "time" wheats the reduction was approximately one-half. This reduction decreased in proportion with shorter "times."

This behavior on long and short "time" wheats indicates that there is a limit to the possible reduction in "time." This is similar to reduction in loaf volume, which is not reduced beyond a certain amount, no matter how poor the flour.

Pepsin reduced the "time" on flours similarly to that of the wheat meal, but direct comparisons on meals and flours from the same wheats were not made.

The protease activator cysteine-monohydrochloride reduced the time on Tenmarq but not on Clarkan. This activator in combination with 0.5 mg. papain reduced the "time" on Tenmarq more than pepsin alone, or cysteine alone. The combination also made a considerable reduction in the "time" of Clarkan.

The protease inhibitor $KBrO_3$ increased the "time" for Tenmarq 2.6 times and for Clarkan 1.5. The protease inhibitor ascorbic acid increased the "time" on Tenmarq apparently as much as did $KBrO_3$, and it made the "time" on Clarkan as long as the check "time" on Tenmarq.

Pepsin reduced the "time" on spring wheats similarly to its reduction on winter wheat. $KBrO_3$ increased the "time" on these wheats beyond the limit of the accurate observation of the endpoint. That is, $KBrO_3$ obliterated the "time" differences among the spring wheats.

While there appears considerable evidence to indicate that the length of "time" obtained on wheat varieties is due to the activity of proteases, this is not proved. Since the "time" on flour is longer than on the wheat meal, it would appear that the location of this protease is not in the endosperm. The disturbing fact is that, as has been shown in a previous paper and will be further presented in another paper, the addition of the bran material to the flour increases instead of shortens the "time." That there is also a gluten quality factor appears from the fact that the effects of the proteases and protease inhibitors were not the same for Tenmarq and Clarkan. Thus while these investigations give informative data, the real cause of differences in "time" on wheats is not clear but needs further investigation.

A CONVENIENT APPARATUS FOR GAS PRODUCTION DETERMINATIONS BY THE BLISH METHOD[1]

J. G. MALLOCH

Division of Biology and Agriculture, National Research Laboratories, Ottawa, Canada

(Read at the Annual Meeting, May 1938)

It is evident from the comparisons made by Eva, Geddes, and Frisell (1937) of the three main types of apparatus for the measurement of gas production, that the pressure method (Blish, Sandstedt, and Astleford, 1932, and Sandstedt and Blish, 1934) is superior to the others in convenience, in the small quantity of material required, and in the low cost of the equipment. Landis (1934) used gauges to measure the pressures. It seemed that the convenience of gauges could be obtained and, at the same time, the cost of the apparatus reduced by the use of a single gauge to indicate the pressure in several fermentation vessels. This paper describes an apparatus constructed on this principle.

Construction of Apparatus

The apparatus is divided into two sections, each having six units. In each section the fermentation vessels are connected through valves and a header, filled with tetralin, to a single gauge. Each section is supported on a light frame which permits raising and lowering into a constant-temperature water bath, $28 \times 10 \times 10$ inches, to which the frames are attached. Figure 1 shows one section in the raised position, while the other is immersed in the bath. The frame consists of ¼-inch brass rod which slides in guides made of ¼-inch iron pipe. The apparatus is held in the raised position by spring catches engaging with slots in the rod. These catches may be disengaged by the little finger of the operator while the rest of the hand controls the lowering. The construction of the apparatus can be best described by dealing with each part separately, and referring to the diagrammatic drawing in Figure 2.

Fermentation vessels.—The vessels were made from 8-oz. De Vilbiss spray-paint cans. These are die-pressed aluminum cans with covers that can be clamped tight by means of thumb screws (*C*) and yokes (*A*) engaging with pins (*B*) on sides of the cans. They have a capacity of 305 c.c. and are very uniform in volume. The leather gaskets were replaced by rubber ones made from a black stock 1/16 inch thick, with hardness 43 (Shore Durometer Type A), fastened in place with Vultex paste. In order to ensure perfect circles, a brass die with two concentric cutting edges was made for cutting the gaskets. The diameters

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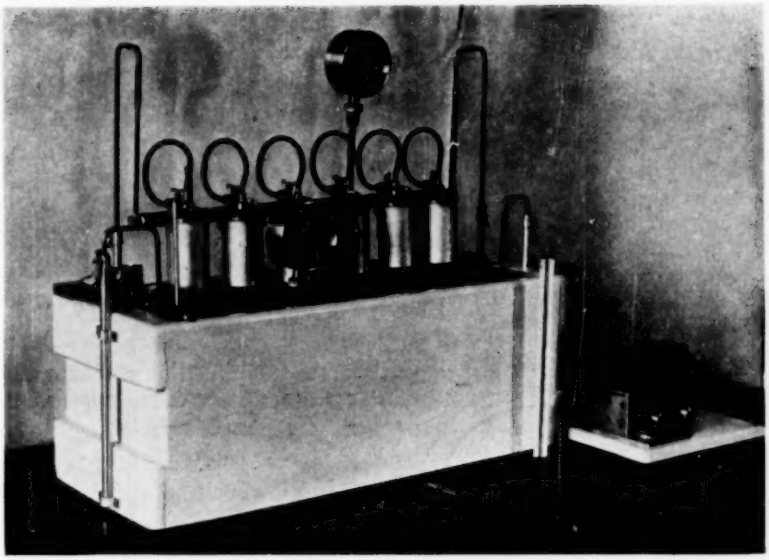

Fig. 1. Gas production apparatus.

of the cutting edges were slightly smaller than the desired size of the gasket to compensate for the stretching of the rubber. The rubber was laid on a cardboard pad and the die pressed through it in a hydraulic press.

The places where the pins (*B*) pass through the walls of the cans were made air-tight with De Khotinsky cement. The vents in the covers were similarly sealed.

The paint tube, which reaches to the bottom of the can, was sawed off. The connecting nut was removed and the inside of the delivery tube was reamed out to take a ¼-inch O.D. copper tube (*D*), which was soldered in place.

Gauges.—These are test-grade Bourdon tube gauges with an accuracy of 0.5%, graduated in millimeters of mercury to 1200 mm. The very small change in volume of a Bourdon tube with increasing pressure makes it possible to use a single gauge for several units as there is practically no movement of tetralin when the readings are taken. It is essential that high grade gauges be used, because cheaper ones have neither the accuracy nor sensitivity required.

Header assembly.—The header itself is made of heavy-wall brass tubing to permit threading in the other components. The ends are closed by screw plugs to which the supporting frame is fastened. Weatherhead needle valves No. 6855 are used to connect each can to the header. It is necessary to repack the glands carefully in order to

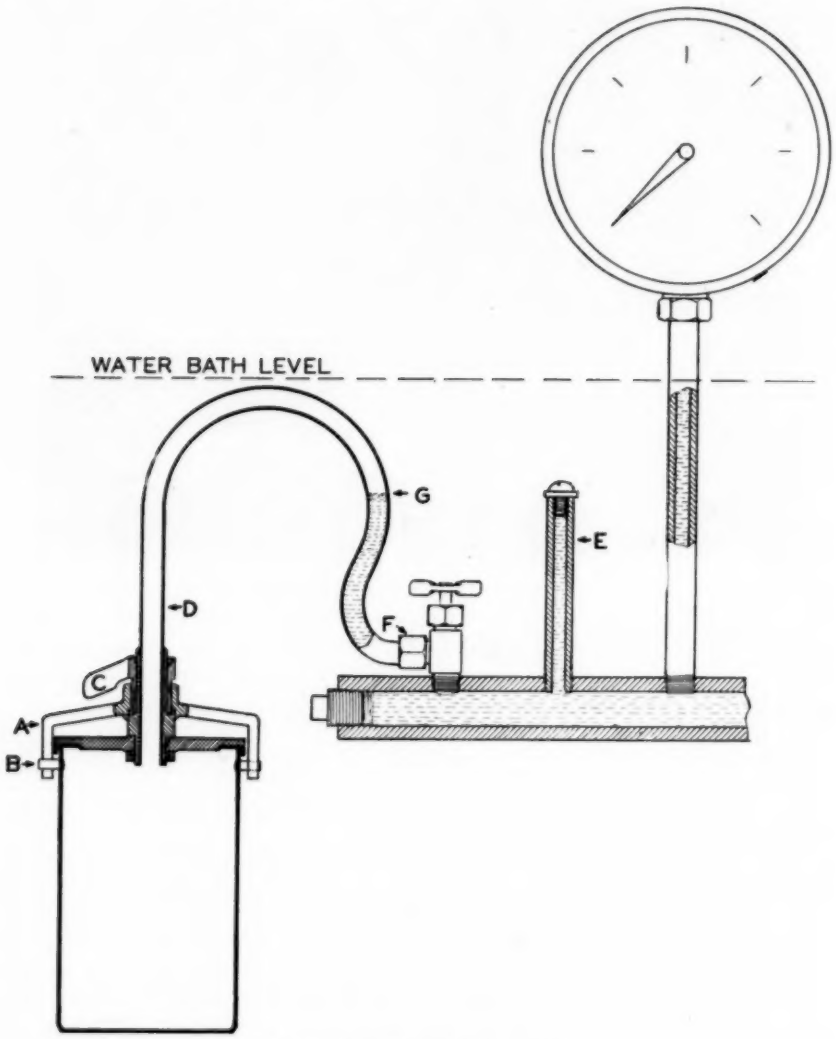

Fig. 2. Construction of apparatus.

prevent leakage under pressure. The header is provided with a tubule (*E*) with a gasketed screw-plug. This is used for filling the header. All the joints were soldered with the exception of that at *F*, which can be pulled tight. After assembly the whole apparatus was subjected to air pressure at 1000 mm. and was found to be gas tight.

Tetralin was selected as the liquid to fill the header because of its high fluidity and extremely low vapor pressure. Before introducing it into the system, the Bourdon tube was blocked in place to prevent

distortion. The valves were closed and the tetralin was run in under vacuum through the tubule (*E*), filling the header and Bourdon tube. The vacuum pump was then disconnected, the valves opened, and additional tetralin poured into the tubule until it overflowed, partially filling the tube to each fermentation vessel (to the level *G*). Finally the tubule was plugged and the pointer of the gauge was adjusted to the zero point as it was displaced slightly by the weight of the tetralin in the Bourdon tube.

Operation

The fermentation vessels are clamped in position and the water bath is brought to temperature several hours before the determinations are to be started, in order that the entire apparatus may be at 30° C. As the samples are made ready, one section is raised out of the water, one of the vessels removed, the sample put in, the vessel again clamped in place and the section reimmersed. If it is desired to release the pressure at the end of five minutes, the section is raised and the clamping screw loosened and retightened. Readings are taken simply by opening the appropriate valve momentarily with the long handled wrench shown in front of the bath in Figure 1, and observing the gauge.

In order to prevent loss of tetralin, it is advisable to have all the valves closed when the fermentation vessels are being put on or taken off. The valves should be open when changes in temperature may take place, in order to avoid strain on the Bourdon tubes.

When the gas production of dough samples is being determined, the doughs are mixed in a miniature paddle-type mixer capable of mixing from 10 to 25 grams of flour, which was constructed in this laboratory. The paddles and bowl are made from the transparent plastic "Lucite" and have proved to be very satisfactory in operation. The mixer is shown beside the bath in Figure 1.

Discussion

This apparatus has proved to be quite convenient in routine operation and fully as accurate as the single pressure meters fitted with manometers. In a special uniformity trial the standard error was 4.4 mm. and the variation determined from the differences between duplicates in ordinary routine determinations was S.E. = 6.6 mm. These standard errors compare favourably with the value (S.E. = 7.97) obtained by Eva, Geddes, and Frisell.

The use of the tetralin-filled header permits the use of expensive high-grade gauges without adding greatly to the expense per unit. The clamping arrangement is more convenient than the lock ring, which requires a wrench and a clamp to hold the cup for its operation. The thin pressed vessels are uniform in size and they quickly assume

the temperature of the bath. Pressed vessels can be made more cheaply in quantity than cast and machined ones, particularly when the material used is difficult to machine, as is the case with aluminum. No release valve was provided in this apparatus but bicycle-tire valves could readily be fitted to the cover of each vessel if desired. The out-of-pocket cost of the apparatus was approximately $7.50 per unit.

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THE UTILIZATION OF SOFT-WHEAT FLOUR

H. M. Simmons

Mid-West Laboratories Co., Inc., Columbus, Ohio

(Read at the Annual Meeting, May 1938)

In considering the utilization of soft-wheat flours, it is found that they appear to fall in three general classifications, with possibly a fourth or miscellaneous group.

Uses of Soft-Wheat Flour

Family	*Cracker and biscuit*	*Commercial bakery*	*Miscellaneous*
Family bread	Cracker sponge	Cake	Starch
Biscuit	Cracker dough	Cookie	Soup thickenings
Self-rising	Pretzel	Sweet goods	
Cake	Cone	Doughnut	
Pastry	Cookie	Pie crust	
Pancake, etc.	Cake	Pastry	

In soft-wheat-producing sections of this country, a large amount of soft-wheat flour is used for family purposes. So, for our first class we have the family flours, which include family bread, general-purpose pastry, cake, biscuit, and self-rising flours. A second class of flours might well be called the cracker and biscuit flour group. Among this group will be found the cracker sponge, cracker dough, cookie, and flours suitable for pretzels and cones. In other words, these flours go into specialized bake shops. A third general class might be called the

commercial bake shop flours. Heading this group are cake flours, pastry, pie crust, yeast-raised sweet goods, such as sweet rolls and cinnamon rolls, and doughnut flours, etc. In the fourth or miscellaneous class are found flours which are used in the manufacture of various other products such as wheat starch, pastes, soup thickenings. This group does not account for a very large amount of flour going into commercial use, and will not be discussed farther in this paper. There is some overlapping in the groups outlined in the above classification; *e.g.* cake flour appears in all three classes. Pastry flours might also appear in all classes.

Family Flours

Let us now take up each of these classes a little more in detail with a view to seeing how well they are standardized, and with reference to some of the problems connected with their utilization. The baking of bread in the home, as we know, is fast becoming a thing of the past, but throughout the rural communities and in the foreign sections of our large cities, the making of bread is not quite a lost art. Throughout the soft-wheat territory, because of price and the skill in its use, soft-wheat flour is the basic flour for home bread making. Because of wide variation in protein strength in different sections and variations from year to year in the quality and character of the protein, soft-wheat mills find it advantageous to blend in hard or spring wheat to maintain as nearly uniform a family bread flour as possible. From the analysis of a great many flours of this type we find the range of protein to be from 9.5 to 10.25%, with viscosities ranging from 90° to 150° MacM. The stronger blends are used in foreign sections of our larger cities, while the weaker blends find use in the rural communities and on the farms.

The general-purpose pastry flours cover a variety of uses, and include flours with a wide range in characteristics. They are, in the main, mostly straight-grade soft-wheat flours, milled and sold in the community producing the wheat. Their uses include family bread baking, all types of home pastry, hot breads, thickening, etc. There is no particular standard for this type of flour, ranging from soft white wheat flour in Michigan to the stronger flours of Illinois and Missouri. Special family cake flours, or packaged cake flours, have characteristics in common with the bake-shop cake flours and will be taken up under the commercial cake-flour group.

Biscuit flours and self-rising flours constitute a large portion of the flour sold in the South, and concerning them a great deal has been written. Our A.A.C.C. Committee on Biscuit and Self-Rising Flours has worked for a number of years on methods of testing and evaluating these flours. Most flours, whether hard or soft, when baked with the

correct formula, give satisfactory results. The confusion arising over the proper amount of shortening to use is due to the different types of flour employed. Soft-wheat flours require less shortening than hard-wheat flours, and often the failure of the housewife to obtain satisfactory results is due to her use of the wrong recipe. To err is human, and with self-rising flours in which two or more ingredients are added to a flour there is sometimes an error. The most common error is the leaving out of one of the necessary ingredients, or sometimes even a doubling up of one of the ingredients, improper mixing, etc. On the past year's crop with its rather high moisture content a great many mills experienced trouble with self-rising flour which contained too high a moisture content. This flour, when stored for some time, lost part of its leavening action, and in some extreme cases showed very little if any remaining gassing power. Too high a moisture content may result in shot balls, even with a prepared flour salt. In some tests conducted a few years ago in the laboratory we found that flours were perfectly safe under 13.5% moisture and there was very little, if any, trouble at 14.0%. But above this figure there was a loss of gas and shot balls formed. We were not using a prepared flour salt.

Too strong a bleach with chlorine or Beta-Chlora produces a lower-volume biscuit. We had one miller making a very short patent flour. He treated this flour to a pH of 5.20 and then added one-half percent of phosphate. Of course his object was to have a high-grade biscuit and cake flour, with the result that he fell somewhat short of either.

Cracker and Biscuit Flours

We now come to the specialized bakery group, headed of course by the cracker and biscuit flours. This group constitutes a considerable portion of the commercially milled soft-wheat flours, and is probably on a more scientific basis than the other groups of flours, with possibly the exception of cake flours. The cracker flours are classed in two groups, the cracker sponge and the cracker dough flour. The cracker sponge flour must be of a type capable of withstanding a rather long fermentation, and at the end of this fermentation, varying from 18 to 22 hours, to be so conditioned that the resulting cracker is not too tough or too brittle. This flour is characterized in the laboratory by a live dough, the loaf showing good spring in the oven with a fairly definite break, and a clean shred. For this type of dough, the cracker baker usually wants an unbleached soft-wheat flour, well milled, with the low grade removed. Such flours are usually made from the stronger red wheats with a viscosity ranging from 55° to 65° MacM., although on previous crops viscosities from 70° to 80° were not uncommon. Viscosities above this figure usually indicate the likelihood of too heavy or too tough a cracker.

For the cracker dough, a soft-wheat flour, somewhat milder than the sponge flour but not as weak as a cookie flour, is required. This flour should be well milled, of about the same grade as the sponge flour, unbleached, and with a viscosity varying from 40° to 50° MacM. This type of flour may be made from the milder red wheats or from a blend of red and white wheat.

Some cracker bakers use only one type of flour for both the sponge and the dough. This flour should therefore border more closely on the cracker sponge type, and flours with viscosities between 50° and 55° MacM. work quite well for this class of bakers. The cracker baker has his difficulties from year to year, the same as the bread baker. This is due to the fact that there are some years in which the gluten is high, with strong characteristics, while in other years the gluten may be lower or of a much milder character.

To the cracker and biscuit trade, biscuits mean all sorts of fancy cakes and cookies, and vary from the size of a dime to that of a saucer. Some of these cookies are on the order of cakes. They rise and have a definite texture similar to cake. Others spread as they are baked, and have no definite texture. For the cake-type cookies, a good grade of soft-wheat flour, having mild gluten, softer than that of the cracker-dough flour, is used. This flour should be treated with Beta-Chlora or chlorine, much the same as cake flours. For the type of cookies which spread when baked, an unbleached flour gives the best results. In fact, if a chlorinated flour is used for such cookies they tend to rise instead of spread. Instead of having ginger snaps we have ginger cakes. In both these cookie flours a milder type of flour is used, and while no definite standards have been set up, it is found that a considerable amount of soft white wheat flour is used, as well as the milder-type red-wheat flours. The gluten content may vary from as low as 6.75% to 7.5%, with a viscosity range from 25° to 40° MacM.

The pretzel and cone flours coming under this classification are far from being standardized. However the late D. A. Coleman pointed out, in a talk before the American Millers Association at St. Louis in May, 1936, that a survey by the U. S. Department of Agriculture revealed that 98% of the flour used by pretzel bakers was either soft-wheat flour or blends in which soft-wheat flour predominated.

Commercial Baking Flours

The use of soft-wheat flour has tended to remain somewhat at a standstill. With the advent of high-speed machinery and modern bakery practice, coupled with improved transportation, the small bakery in the soft-wheat territories has found it advantageous to swing to the

hard wheat flours for his bread baking. Nevertheless, during years of strong soft wheat, such as we had in 1934, considerable soft wheat was used in bread baking, because of a favorable price. However, for pastry, sweet goods, and cakes, the commercial baker has increased his use of soft-wheat flour.

For pastry and pie-crust use, a considerable amount of the lower-grade flour finds favor with the baker. The protein may be high, but it is of a mild quality and is economical on shortening. There are some who have treated the flour with Beta-Chlora or chlorine in order to reduce the gluten strength. This has a tendency to give a very thick mealy pie crust, having a light color, whereas the untreated lower-grade flours tend toward a thinner crust, somewhat flaky, and having a natural brown color. Aside from the lower-grade flours, the weak "starchy" flours are used very successfully by the pie baker. If we were to set a viscosity range for this class of flours, it would be from 25° to 35° MacM. In our laboratory experience we have found that an excess of water will invariably produce a tough crust. Apparently when too much moisture is added there is some development of the gluten in the mixing. In the official method (tentative) for testing pie flour (A.A.C.C., 1935) the formula calls for from 50% to 64% cold water. In testing soft-wheat flours for this purpose, I find from 35% to 40% absorption gives much better results. Also, this formula calls for 60% shortening, which tends towards too rich a crust with the majority of soft-wheat flours.

Probably the greatest increase in the use of soft-wheat flour by the commercial baker has been for the baking of cakes. This is partly due to the housewife's desire for more leisure time and to the improvement in the bakery cakes, which are now made on a more scientific basis than they were a few years ago. A high-grade cake flour must now meet certain specifications in order to produce a cake with a good volume and a silky texture and be capable of carrying a large amount of sugar. The proportion of flour used in cakes is much smaller than it is in any other class of baked goods, but this flour must be capable of doing its part. The flour content of some high-sugar-ratio cakes is as low as 28% of the total batter. The protein content may vary from year to year, but the average will be around 7.5% to 8.0%. This gluten should be of a natural, moderately mild quality, with a viscosity around 50° MacM. Some successful cake flours run somewhat higher than this, and on this year's crop many are running much lower, but some slight adjustment in the cake formula is necessary. While ash apparently has no effect on the cake-baking properties of a flour, it is indicative of good milling. Those streams which produce the best cake flours are naturally low in ash and as a result it is said that a cake flour should

be low in ash. Probably the majority of cake flours have an average ash content of from 0.32% to 0.34% on a 13.5% moisture basis.

One factor which seems to have received too little attention, and which has caused no little grief in the baking of cakes, is the moisture content of the flour. This has been particularly noticeable on this last year's soft-wheat crop (1937–38), which had an abnormally high moisture. This should be given consideration, especially in the high-sugar-ratio cakes, where the formula calls for a high percentage of added liquid. A high moisture in the flour may be just enough to unbalance the formula, causing the cakes to fall and produce very definite sugar lines. This is very plainly shown in Figure 1. This flour was received in the laboratory and baked with the results shown on the right. The analysis of this flour was very good, with the exception of the moisture content, which was 14.9%. This flour was then dried over night to a moisture of 12.6%, and re-baked the following day, with the results shown on the left. The high-moisture cake showed less volume, even before it fell, and a soggy sugar line through the center.

Fig. 1. Effect of excessive moisture on cake properties.

I believe the high-sugar-ratio cakes are more critical, or we might say have a smaller moisture tolerance than the older-type cakes. It might be well in the development of new formulas in the future if all the characteristics of flour were taken into consideration. One very important factor in cake flours is the proper treatment with Beta-Chlora or chlorine. The ideal treatment seems to be that producing a pH of 5.20. This of course may vary from 5.10 to 5.30. Less acidity tends towards coarser texture and smaller volume, with untreated flours giving the same results in high-ratio cakes as observed in the cake with too high a moisture content, namely falling in the center and having a pronounced soggy sugar line. Too strong a treatment, say with a pH below 4.75, tends toward lower cake volume and instability so far as the keeping qualities of the flour are concerned.

Even with fairly definite standards for cake flours available, those offered to the trade cover a wide range and cause no little confusion. The low-protein, low-viscosity white wheat cake flours are often sold

to a trade which has been using a much stronger flour made from some of the stronger red wheats, or *vice versa*. These same conditions in baker's cake flours also apply to the packaged cake flours used by the housewife.

In conclusion, it may be said that soft-wheat flours find their outlet in a multitude of products, and only in a few cases have fairly definite standards been set up. The setting up of more definite standards (keeping in mind the variation occurring in soft wheat from different sections from year to year) and the obtaining of the co-operation of the entire baking industry in conforming to these standards, will aid greatly in the milling of soft-wheat flour and encourage the use of these flours on a more extended scale.

THE TECHNIC OF PRODUCING A NEW SOFT WHEAT [1]

W. W. WORZELLA [2]

Purdue University, LaFayette, Indiana

(Read at the Annual Meeting, May 1938)

Three general methods are used in obtaining new wheat varieties, namely introduction, selection, and crossing. By introducing new strains from other states and countries and comparing them with known commercial varieties, new wheats may be found that are suitable and adapted for a particular locality. The variety Turkey, grown very extensively in the hard red winter wheat region (and introduced from Russia), illustrates this method of improvement. When the selection method is used, several hundred heads of various types are isolated from the best commercial varieties. Each is grown separately and tested in comparison with suitable standard varieties with the hope that some will be more desirable than those already grown. Trumbull, a soft winter wheat selected from Fultz, was developed by this method.

The introduction and selection methods have been used for many years with great success. Their use, however, is limited since most of the better varieties and selections already have been tested, and furthermore, one is limited to only those types produced by nature. If the types desired are not available it is up to the agronomist to create or "build up" such new varieties. This is done by crossing, the method most extensively used in developing new wheats.

Before taking up crossing as a method of developing new wheats,

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[1] Contribution from Department of Agronomy, Purdue University Agricultural Experiment Station, LaFayette, Indiana.

[2] Assistant in Agronomy.

it seems desirable to emphasize several important concepts. First of all, to an agronomist, wheat characters are his units or "building blocks." He has many parental wheat varieties that possess one or more outstanding characters. The characters are analyzed into their individual components and the characteristics and behavior of each studied. These are then synthesized into new combinations or types as demanded by the grower and trade, just as the chemist selects his chemical elements, studies their properties and characteristics, and then synthesizes new compounds.

An analogy may be briefly drawn between the various parts of a house and wheat characters. Because of its importance in a new wheat, yielding ability may be thought of as the foundation. The windows represent the individual components of quality; the heating system indicates winter-hardiness; the siding, paint, and insulation, disease resistance, etc. Most of these characters are very important and must be considered in developing a new variety. A wheat possessing only high yielding ability, however, is as complete as a house with only the foundation. Obviously, all characters do not have the same relative importance, because of their nature or the conditions under which they are grown. For example it is immaterial whether a wheat possesses white or brown chaff, whereas it is imperative to have desirable winter-hardiness, high yielding ability, disease resistance, and suitable quality. Likewise, a variety grown in the north must possess greater winter-hardiness than one grown in the southern states.

In developing new varieties, therefore, an agronomist has specific objectives in mind. In the soft winter wheat region special emphasis is given to the combining of high yield with winter-hardiness and greater disease resistance, together with the suitable quality already found in these wheats. The crossing method is used in synthesizing these new combinations. Before making the cross, however, great care is taken in selecting the proper parents, since one or the other parent must have the characters that are to be combined. After suitable parents have been selected the cross is made. Figure 1 shows the floral organs of a single wheat flower.

In making the cross the head or spike is trimmed to about 16 or 18 flowers by removing the lower and upper spikelets. The anthers, while green, are removed from each flower by pulling them out with a pair of forceps. A glassine bag to prevent contamination of foreign pollen is then placed on the emasculated spike, and the female parent is properly labeled by means of a small tag. Pollination is usually done two or three days after emasculation. Anthers of the male or pollen parent, which are yellow and ready to dehisce pollen, are gathered in a small bottle or watch glass. The glassine bag is removed from the female

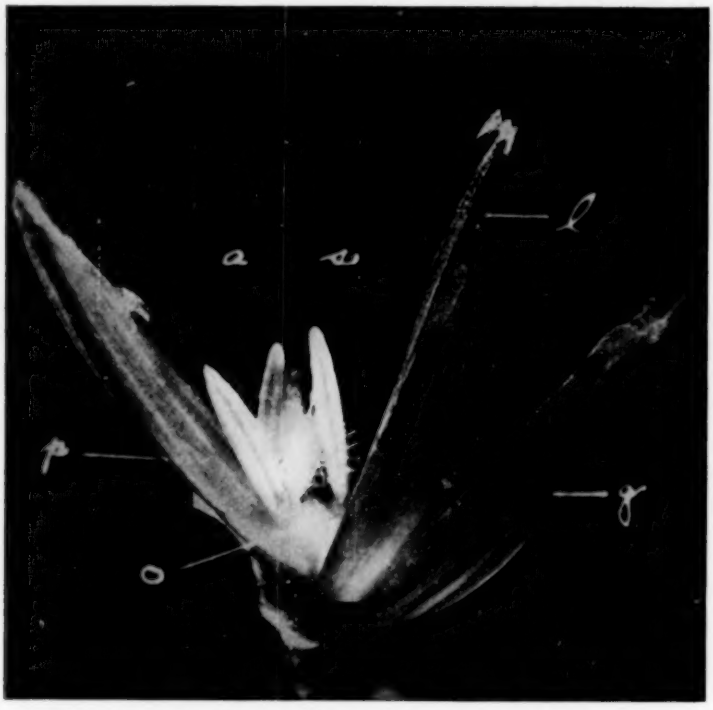

FIG. 1. Photomicrograph (× 10) illustrating the floral parts of a wheat flower: (*a*, anthers; *s*, stigma; *o*, ovary; *l*, lemma; *p*, palea; *g*, glume).

parent and the ripe anthers containing the pollen are placed on the stigma of each flower. The glassine bag is then replaced, the male parent recorded on the tag, and the bag left on the head until harvest. The cross presumably has been completed, and if successful, a few F_1 grains should result.

When a cross between two varieties has been made and the grain grown for a few generations, many new types and combinations have been synthesized. The task of the agronomist then is to discover the desirable new combinations. This is done by rigid and systematic selection which includes both rejection and retention, since only a very few of the new strains from any one cross are found to be desirable. The progressive steps in breeding new wheats during the early segregating generations are briefly illustrated in Figure 2.

Starting, for example, with a single F_1 cross obtained in 1930, a year elapses before F_1 plants bearing a few hundred grains are produced. These grains are planted in the field by spacing them in rows. The following year each plant is examined and only the desirable types are continued in short rows as shown in Figure 3.

The plants in these rows in turn are examined and studied, and from the most promising ones, head selections are made for the following planting. This process of reselection is continued for six to eight years. This period is very important in a breeding program and

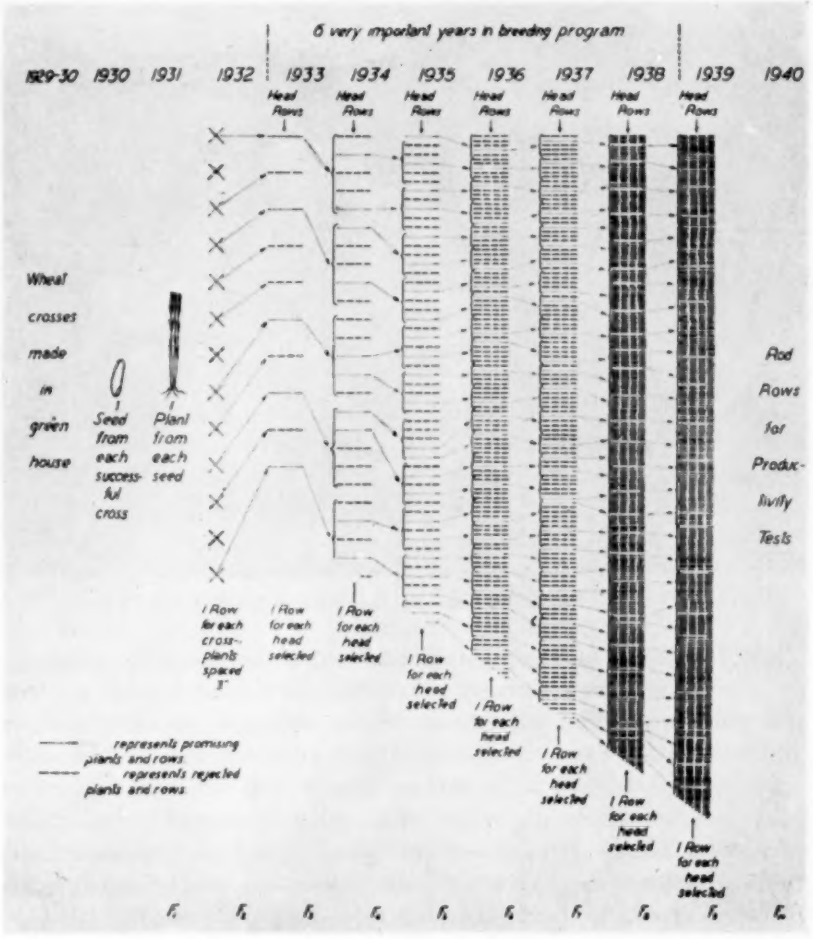

Fig. 2. Progressive steps in breeding new wheats during the early segregating generations.

the most difficult to the agronomist. Each year several thousand strains are grown, examined in the field, and the more desirable ones harvested. Each year several thousand samples, representing only 10 to 20 grams of wheat of each strain, are examined and tested for size, type, quality, etc. Simple characters, such as maturity, beards, shattering, strength of straw, height, type, etc., are readily recognized and are

used as a basis for selection. The more complicated characters, such as quality, winter-hardiness, and yield, cannot be recognized by merely observing the plants or the sample of grain. The agronomist therefore depends on specific tests or "performance tests" to guide him in the desired direction as to quality, winter-hardiness, and yield.

Fig. 3. Four-foot rows in which new selections are grown, reselected, and purified.

Obviously, the more simple characters that may be easily recognized are used at first as a basis of selection. As the work proceeds, each new combination that is selected is then subjected to numerous performance tests. The first of these is the quality test to ascertain milling and baking value. In Indiana three simple tests are used to measure the important components of quality, (*a*) the wheat-meal fermentation-time test as a measure of gluten strength, (*b*) the granulation test with which is obtained the degree of particle fineness, and (*c*) the carotenoid-pigment content to determine desirable color. Fortunately all three tests can be made in the early segregating generations, since only a small quantity of seed is required. Later, when sufficient grain is available milling and baking tests are performed on all strains before being released for commercial production.

All strains that appear satisfactory for the simple characters and meet the qualifications of a suitable soft wheat for pastry purposes, are then subjected to the winter-hardiness tests. This involves replicated field tests as well as growing seedlings from each strain under

field conditions and subjecting them to an "artificial winter" produced in a refrigeration chamber. Only those selections which meet these severe tests for cold resistance are retained.

Strains that have survived six to eight years of rigid selection and appear quite satisfactory and pure for the characters examined, are then advanced for yield trials in rod rows as shown in Figure 4.

FIG. 4. Rod-row nursery in which yielding ability of new strains is determined.

Yield trials in rod rows are conducted over a period of four to five years in an effort to test seasonal, soil, and locality adaptation. Those strains that consistently demonstrate superiority in yielding ability, as well as quality, winter-hardiness, disease resistance, etc., are then advanced to multiplying plots and field test plots. The number of strains to reach this test, for obvious reasons, is very small. Those that do are tested not only at the central station but also at several outlying fields located throughout the state under different soil and climatic conditions. Check plots, seeded with standard varieties, are grown with these for the purpose of comparing yields and other agronomic and physiologic characters. In addition, one or two of the most promising strains are further tested in special disease and winter-hardiness nurseries located throughout the United States. These are conducted co-operatively between the United States Department of Agriculture, Bureau of Plant Industry, and State Agricultural Experiment Stations.

If a strain consistently demonstrates superiority during the 12 to 15 years of rigid and systematic testing, it is then recommended for distribution and commercial production. This does not mean that the final goal in wheat improvement has been reached. Wheat breeding

is a gradual process in which improvement in the various characters is made step by step. As the breeding program advances and further information is obtained on the nature and inheritance of characters, better varieties will continually be released that will possess high yielding ability, more winter-hardiness, greater disease resistance, and at the same time the desirable quality characteristic of soft winter wheats.

SOFT WHEAT MILLING

R. F. Sopher

Acme-Evans Milling Co., Indianapolis, Indiana

(Read at the Annual Meeting, May 1938)

In the mind of the writer there cannot be too much emphasis laid on the cleaning and conditioning of the wheat prior to milling. The cleaning, blending, conditioning, and the milling of the soft varieties of wheat deserve the same careful consideration as do the hard varieties. In fact, in the soft wheats in some sections of our country, we are confronted with a problem that is not generally experienced by millers of the hard varieties—that is, wheat that is infested with garlic or onions. This is more generally found in the regions south of the Ohio river and really gives the millers, in what we sometimes term as the Deep South, that is, the Carolinas, Virginia, Tennessee, and others, plenty to worry about. Fortunately, the soft-wheat millers further north are bothered very little if any.

Like most varieties of wheat grown, soft wheat has a certain amount of seeds, cockle, cheat, oats, and so forth. By using modern grain-cleaning equipment, the operator should have very little difficulty in eliminating this trash material. For instance, there has been a considerable improvement in the machines to eliminate seeds, cockle, oats, and so on. These machines are of the indented cylinder and disc type. Either one will do a very efficient job.

Where aspiration is required, you will find that most companies building grain-cleaning machines have greatly improved their equipment, especially where an air separation is used. In fact it is now possible for an operator to secure an aspirating machine that is self-contained. The use of such a machine in certain localities and plants has its advantages, one being that no air is expelled to the outdoors, which of course is a factor in cold weather. On the other hand, this type of machine is not as efficient as the disc-type aspirator, one where the air is blown into a dust collector of some type. These disc machines make a much better separation on fine dust particles.

As for the scouring equipment there have been many marked improvements during the past few years. We are now in a position to buy equipment that will do a very mild job and at the same time a moderate amount of aspirating. Then again we are able to purchase machines that have unusually well designed aspirating chambers, and at the same time they are in a position to offer partial carborundum cases when wanted and by so doing afford the operator a means of doing a very severe job of scouring the wheat when so required. In short, if one really wants to do a thorough job of grain cleaning today, the proper equipment is now available, and it is simply a matter of planning the installation carefully and then making the necessary purchases.

The problem of removing garlic or onions from wheat is a very difficult one and there are very few ways in which this can be done with any degree of success. The one method is that of drying the wheat down to a very low moisture content, which has a tendency to leave the garlic lighter than the wheat, which in turn makes it possible to remove by means of suction a considerable amount of the garlic from the entire stream. This system is a very costly method and is not extensively used for that reason. Another method that is recommended by one of the leading mill builders is as follows:

"We believe that the use of water on rolls is probably the most common method. In some cases the rolls are washed after shutting down, but where water is applied while the mill is in operation, the water is put on a very small section of the roll, which allows a dough ball to form. As this dries out, the centrifugal force of the roll throws off big chunks or sections. This is repeated down through the length of the roll, and this cleans the corrugations very readily. It is desirable with this system to put a scalping shoe below each pair of rolls while water is applied to remove the dough balls or chunks, thus preventing them from going down into the system and causing choke-ups in the sifters."

Where an operator is not equipped to remove garlic or use water as just mentioned, then he is left with only one alternative, and that is, he must shut down the plant whenever the roll corrugations fill up and give them a thorough scrubbing, because as might be expected, when these roll corrugations start to fill up, it is utterly impossible to reduce the wheat in a way that will conform with the general program of the mill. When the rolls are in this condition, it quite naturally affects the quality of the flour, percentages of the various grades, and also the yield.

After one has his wheat thoroughly cleaned he is then confronted

with the job of tempering or conditioning. By that I mean the amount of water necessary to put the wheat into proper condition for milling. In soft wheat raised east of the Rockies we seldom are confronted with the necessity of predampening. In my opinion, to secure the maximum of benefits from conditioning, the miller and the chemist should work hand in hand, because no matter how refined your milling process may be, without proper preparation of the grain one cannot hope to make the best product possible out of the grain furnished him for flour-making purposes. It is quite true that a great deal depends upon how the operator has his mill set or diagramed, the type of flour that it is necessary to make, etc. Grain conditioning is a most important part of the milling process and requires a great deal of study and a lot of attention.

The problems that one encounters in the breaking process differ greatly from year to year, and quite frequently after a crop starts to move the operator finds it necessary to alter the type of corrugations used. This sometimes does not have to be done all the way through the system. Frequently, by changing just a couple of the breaks, the results wanted can be secured.

As for the breaking of soft wheat and hard wheat on the same rolls, this presents quite a different problem. I mean that the operator is forced to use the type of corrugations that will give him a satisfactory yield and obtain the maximum results on the softer varieties of wheat. It should be quite apparent that if a very vitreous type of wheat is ground on these same machines, one cannot expect to secure good results for the reason that there is a tendency to shatter these hard berries, which makes it almost impossible to grade and purify the middlings in a way that is comparable to a mill designed for the milling of hard varieties only.

In designing a mill the engineer must constantly keep in mind a balance between the grinding capacity, the bolting capacity, purifying, and other factors. A mill is really made up of five distinct divisions: the breaking process; the sizings, or that part of the system where the large middlings are lightly ground so as to make it possible for one to eliminate the germ from the better stocks and purify a portion of the balance; the middlings system, which is that part of the system handling the choice flour-making parts of the berry; the tailings system, which is that part of the mill where one gathers up the fine brany particles, reducing them in a way so there is no loss of flour into feed; and the last is the low-grade or finishing systems where the last bit of good flour is obtained. It is, therefore, quite important that great care be given to the placing of the equipment for sifting out the flour and making the other separations.

All too often does the operator find that in the milling of soft wheat he is in no position to add to the bolting capacity. The reason he might want to add to this capacity is that occasionally the company desires to change the type of flour it is producing, or one may meet with a very soft crop and consequently find that it is imperative to do something to properly dust the flour out. If this cannot be done, the operator has only one alternative and that is to reduce the capacity of the mill to a point where the bolting machines will perform the work in a satisfactory manner.

Fortunately, during the past few years, there has been brought out by the various manufacturers of milling machines, a number of different types of small sifters. These run at a high speed with a small throw, and they really do have considerable capacity. When one finds himself short on sifting capacity and crowded for space, he may be able to use one of these small sifters to a great advantage. In fact such a machine inserted in the flow plan would have a tendency to make the mill quite flexible at any time.

Frequently the question has been asked of me, " Why is it that soft-wheat mills are so often bothered with choke-ups? " To me there really is very little excuse in the present-day flour mill for being bothered to any great extent with chokes, because it is simply a matter of studying the degree of pitch required in order that the various types of stock in a flour mill will flow freely. If one finds that the proper fall cannot be had because of the distance between floors or machines, he would be much better off installing a few short conveyors than be bothered with flour stocks spilling all over the floors and becoming contaminated with dirt.

SOFT-WHEAT TESTING PROBLEMS

GEORGE L. ALEXANDER

The Commercial Milling Company, Detroit, Michigan

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The literature of cereal chemistry dealt almost entirely with hard-wheat problems until a few years ago. The cereal laboratory had its origin and early development in the hard-wheat sections, and the millers of soft-wheat flours were not greatly interested in laboratory tests until they felt the pressure of loss of sales outlets. In earlier years the soft winter flours were commonly used in commercial bread production as well as for cakes, pastries, and crackers; but with improved milling and maturing technique, and the mechanized bread-making methods,

the hard-wheat flours largely displaced the soft with this most important class of consumers. It was at this point that the soft-wheat millers enlisted the aid of cereal chemistry to develop new outlets for their products; and specialized flours increased in numbers. The greater part of the output of the larger soft-wheat mills now is shipped to a variety of food manufacturers, each with his special performance requirements.

Hard-wheat flours are used almost entirely for making yeast-leavened bread and can be tested and judged rather uniformly according to certain standards for gluten strength and character, and enzymatic properties. The many uses to which soft-wheat flours are put requires that more of the flour characteristics must be controlled; and the soft-wheat laboratory must be prepared to conduct a wider variety of tests, particularly baking tests, than the hard wheat laboratory. Likewise the interpretation of soft-wheat tests requires a somewhat different viewpoint than in the case of hard-wheat tests. The utility and appreciation of soft-wheat flours is tied up more with delicacy, tenderness, flavor, and eating quality, rather than with strength, gassing power, and the ability to withstand "punishment" as in hard wheats. The term "strength" is also heard in connection with soft-wheat flours, but is used merely in a comparative sense. In very few cases is a "strong" soft-wheat flour comparable in gluten strength with even a "weak" hard-wheat flour. Another important difference is that hard-wheat flours are made with the expectation that they will be used in a manner which will greatly modify the gluten and other characteristics, with special reference to the action of dough mixers, yeast foods, and fermentation. Soft-wheat flours, on the other hand, are usually so balanced that they are ready to give the desired results with only the mild changes caused by a gentle mixing action.

The reason for specialized soft-wheat flours is that the best quality of products and greatest economy are realized through their use, in that they are milled and matured from selected wheats and mill streams to suit the bakers' processes.

The biscuit and cracker bakers require three types of soft-wheat flour, these being the cracker sponge flour, the cracker doughing and hard sweets flour, and the cookie flour. These differ considerably in both analysis and in performance and may have to be drawn from widely separated milling sections.

The larger cake bakeries usually employ three or four types of soft-wheat flour. There is the very short patent, highly bleached and finely granular flour, suited for angel foods and for formulas with a very high percentage of sugar and liquids and for cakes requiring a very white crumb. The next grade may be the longer patent, also well

bleached, and used for loaf cakes, the cheaper layers, sponge cakes, and general purposes. A third grade of flour may be used for pastries and a fourth grade for cookies.

Pretzel bakers and bakers of many other specialties have each their own requirements in soft-wheat flours. These requirements may be vastly different but have been found from experience to be necessary for the proper balance of quality and production costs in the plant in question. The point to be made here is that it has been found more profitable to assume the greater trouble and cost of obtaining specialized flours than to make the easily available flour work by changing formulas and processes. Smaller plants may be forced to this expedient by lack of capital or storage space, but larger plants carry the necessary line of flours.

It is unnecessary to remark that the production of specialized soft-wheat flours requires very close co-operation between wheat buyer, miller, and chemist, with the latter as the control man and source of information. The character of a flour is determined principally by the variety and quality of the wheat composing the milling mixture. The miller, in conjunction with the laboratory, may do much to bring out the proper qualities in a flour, but the basic character of the finished product must be founded on intelligent wheat selection and blending. Numerous soft-wheat varieties are being grown in the soft-wheat areas, and there are important differences in the baking properties of their flours. It has also seemed to the writer that, possibly because of a more irregular climate and rainfall in the soft-wheat sections, the soft wheats tend to show greater changes in character from one crop to another than is the case with hard wheats. These seasonal changes are made the more important because specialized soft-wheat flours must be more accurately balanced than bread flours need to be.

The narrow margins on which flour is sold prevent shipment of wheat for long distances except in seasons of extreme quality changes. This sometimes leads to pressure on mill production men, including chemists, to make them adapt available wheats, which would not be acceptable under more normal crop conditions. Thus we have noted attempts to offset extremely low gluten strength by blending strong hard wheat with the soft, or the blending of starch with the flour from wheats that were too high in gluten strength or had harsh characteristics. In these instances the analyses may be brought into line but not the baking qualities. In years of soft-wheat scarcity the cracker bakers have tried to use hard-wheat sponge flours, but to the best of my knowledge this penalized the appearance and eating qualities of the crackers too much to suit them. The same has been the case where high "strength" has been offset by using a diluent of starch in cake flours. Possibly such expedients may

be workable someday, but at the present time it is well to be wary of makeshifts in the production of specialized soft-wheat flours.

In addition to his wheat charts the soft-wheat mill chemist should have a detailed knowledge of the mill streams, the effects of bleaching and maturing agents, and the performance of his flours under varying baking and processing treatments. It may be necessary to work out a new type of flour on short notice, and this information should be at hand. An understanding of the action of doughs and batters is essential in selecting suitable flour for any purpose. It may be that under certain conditions a lower-grade flour is indicated rather than a short patent, or an unbleached rather than a bleached flour. Type of maturing agent is quite important, as is the flour granulation size. Green or underaged flours may work best sometimes, or the use may indicate a flour which has been well aged and matured. The effect of treatment in flour driers is important, as marked alterations in colloids can take place in these machines under certain conditions. None of us will ever find out all we should know about our mills or our wheats, and spare time should be spent in a continual search for information and new methods for attacking our problems.

Commonly used tests in soft-wheat laboratories are those for percentage of moisture, ash, and protein, for absorptive power, color, viscosity, hydrogen-ion concentration, and granulation (A.A.C.C., 1935). There are a number of methods for determining gluten qualities, and the number of baking tests equals the number of uses for soft-wheat flours. Technical organizations, including the A.A.C.C., have had active committees working on these testing methods for years, and improvements are suggested almost annually. There is much friendly controversy respecting the merits of different methods of testing, which is a healthy, constructive condition. In the following discussion it is hoped that the opinions of the writer are accepted for what they are, that is, the results of experience, or the observation and application of information generally known and published.

The moisture test is empirical in character, and is reliable only when conducted under strictly controlled conditions. There are a number of devices for determining moisture in cereal products, and the physical make-up of the material tested has a great effect upon the type of apparatus. Water is understood to be present in flours in three forms—free moisture, combined moisture, and moisture of composition, and they are expelled from the tested flour in that order when the flour is exposed to heat and vacuum. The free moisture is expelled rather easily, but the moisture of composition passes off only when heating is sufficiently severe to scorch or partially break down the flour. Moisture tests should be made only by recognized, official methods, and the rules

for the test should be uniformly observed in order to achieve uniform results between laboratories. Flours and wheats tend to reach a state of moisture equilibrium with the surrounding atmosphere, and will take up and give off moisture according to whether the air is humid or dry. Hence laboratory samples should be taken and kept, until tested, in sealed containers of metal or glass.

Moisture is more closely held by some wheats and flours than by others. This was very apparent when we replaced the familiar Brown-Duvel moisture apparatus with the 130°C. drying oven in wheat temper control work. It was found that hard wheats, of higher protein content, checked in moisture results as between the two types of tests, but the soft wheats yielded about 1% higher moisture results in the severe drying oven as compared with the comparatively mild Brown-Duvel. The logical explanation was that the more severe method of drying released a greater amount of the combined moisture in the soft wheats, while the hard wheats withstood the same condition. In other words, the increased vapor pressure produced in the hard wheat by the oven method did not overcome the affinity of the hard wheats for moisture but did so in the soft wheats to some extent. We found, however, that by applying this 1% correction we were able to make this change in testing methods without disturbing our control schedule for tempering.

Soft wheats are grown in areas having milder climates and good rainfall, and usually come to market containing a larger percentage of moisture than in the case of hard wheats. At the same time soft wheats cannot safely be stored at as high a moisture content as hard wheats, and are more likely to sprout and spoil. Being of softer texture, soft wheats are not tempered as heavily or as long as hard wheats, and are milled with a lower moisture content at the first break roll. It is sometimes the case, in years of heavy rainfall at harvest time, that the wheat is received with too high a moisture content for milling and actually has to be dried before sending to the rolls.

One of the principal reasons for control of moisture in soft-wheat flours is to maintain soundness. This applies principally to such flours as go into the warm, sultry, Southern sections. Flours for this trade are, as a rule, heavily bleached, which in itself shortens keeping time, and in storage conditions where drying out is slowed and temperature is favorable for the growth of mold and other organisms, flour moistures should be held down at the mill. Flours milled at very high moistures seem to suffer a loss in gluten strength in milling, possibly because of the higher roll pressures and consequent heat under such conditions.

The ash test has been used by cereal chemists for many years, and there is a great deal of literature on the subject of ash in flour. Essentially this determination is made to help the production man in the mill

in the control of flour grades and uniformity, or to give the flour trade a guide for establishing grades and a basis for uniformity in flour shipments. Low ash content in a flour indicates that it is a short extraction, very cleanly milled, from wheat of low mineral content, or a little of all three. Most soft-wheat flours are required to have a soft, pliable gluten; and shorter-extraction flours, as indicated by low ash contents, usually have this type of gluten. As the ash content rises and the grade of flour goes down, the gluten will tend to be tougher and shorter. This is due, at least in part, to the buffering, binding action of the higher amounts of mineral matter in such lower grades. Higher ash content is also associated with darker flour color.

Soft-wheat flours tend to contain less ash, grade for grade, than hard-wheat flours; and the ash is more volatile when heated and more hygroscopic when cool. These properties indicate a difference in the mineral composition. Soft-wheat flours burn out more quickly than hard, and tend to fuse unless properly handled. We have had improved results in ashing soft-wheat flours since using the spun nickel crucibles recommended by H. W. Putnam in a paper which he read at the January, 1938, meeting of the Cincinnati section. With this type of crucible the tendency toward fusing of the ash or scaling of the crucible, as in the case of porcelain and silica crucibles, was greatly diminished.

Color scoring is one of the more important and probably one of the oldest means of grading flours. The only method which has been generally successful has been the Pekar or "slick" method, where the flours are smoothed down side by side on a paddle, then dipped in water and dried. There are objections to this method; and the method of handling, age, and moisture content of flour, and method of drying do affect the comparisons. Color analysis has been tried in which the proportions of red, yellow, black, and white have been determined, but these were not sufficient because they did not show the brightness or "bloom" which the trade associates with a properly milled flour.

While some special flours should be unbleached and of yellow color, the greater portion is required by popular demand to be white or bleached. The most satisfactory color results from the use of good wheat and proper milling, and the writer prefers to consider bleaching as a means of maturing the flour to bring out baking properties rather than merely a method of oxidizing the yellow pigment it contains. A properly matured flour is likely to show a better crumb color, the true measure of flour color, than one which has been bleached until the flour is very white. It is generally accepted that soft cookie or pastry flours should be left unbleached or else lightly treated with some agent that does not affect the gluten, such as NO_2. Soft flours to be used in bread or biscuits will be strengthened if treated with NCl_3. Cake flours

should be bleached with Cl_2 and where an extra-white color is required, any of the above bleaching agents may be used in combination with benzoyl peroxide or a similar agent.

A test for the hydrogen-ion concentration is widely used to control the rate of chlorine bleaching of cake flours. Both electrometric and colorimetric or indicator methods are used. The electrometric or potentiometer method is more scientific and gives finer readings, but the use of the apparatus requires greater technical ability. Notable improvements in this type of equipment have increased its use in the past year or two. One of these improvements has been the perfection of a durable and accurate glass electrode; and at this time several makes of compact, self-contained pH meters are available, with standard cells for ready, quick reference in checking readings. However, many small laboratories continue to use colorimetric methods because they are adapted to the use of routine technicians with limited scientific training. This method is sufficiently accurate to control chlorine bleaching within satisfactory limits of variation.

Cake-flour millers have known for some years that a good chlorine bleach was essential for proper baking performance in light cakes. The action of the chlorine bleach has never been worked out in detail, but it has been observed that flours with too high a pH, if used in connection with rich formulas, tend to rise in the oven but fall or shrink when taken from the oven. Some light is shed on the subject by L. H. Thomas, an expert in the manufacture of wheat starch and gluten derivatives, and I quote him directly (personal communication, 1938).

> Chlorine has been used for years to produce the so-called "thin boiling starches," which are starches which reduced capaciy for swelling in boiling water. More recently it has been found possible to control this process; and it has been discovered that in the initial stages the swelling capacity of the chlorinated starch has been greatly increased over that of the natural starch.
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> With regard to the dispersion of gluten by negative ions, we have found it impossible to wash out gluten in our commercial starch process if the flour has been previously treated with chlorine. In the laboratory we have studied the dispersion of pure gluten, and found that at a pH between 5.2 and 3.0 the gluten was dispersed into such a colloidal condition that at certain concentrations it could be whipped much like egg whites.
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> The dispersion of the gluten by chlorination reduces the doughing tendency of the flour; and mixing with other ingredients of the cake batter undoubtedly keeps the gluten dispersed even though the pH of the batter is higher than that of the flour. Another factor may be of major importance. That is the greater capacity of the dispersed gluten for taking up water. Naturally any ingredient which takes up water in this way must have a material effect on the character of the cake batter.

Mr. Thomas has found that chlorination of flour produces marked dispersion of the gluten, as well as an increase in the hydration capacity of the starch and gluten in batters. The practical baker knows that he cannot raise the percentage of sugar in a cake formula without also increasing the liquids. The moisture-carrying capacity of a flour, as

well as the pliability of its gluten, determines its performance in a cake formula. Thus the effect of bleaching cake flours with chlorine is somewhat clarified. High-grade cake flours are usually chlorinated to a pH of between 5.0 and 5.2. The amount of chlorine necessary to do this will depend upon the extent to which the flour is buffered, but one ounce of chlorine per barrel will reduce the pH of a patent flour about 0.25 pH unit if the flour consists mainly of streams from the purified middlings stock. The degree of chlorination necessary for best baking results will vary a little from crop to crop.

Flours to be used in biscuit and bread baking should not be subjected to the gluten-dispersing action of chlorine, as they need all the gluten strength possible in such naturally weak flours. Flours treated with chlorine tend to make somewhat sticky doughs, which are not easy to handle and mold. A low pH is also undesirable in flours designed for cookies and pastries which are supposed to bake out tender and crisp. Chlorinated cookie flours will be reduced in plasticity of dough, or spreading ability, and will lack spread, top grain, and crispness unless the formula is enriched or additional leavening is added.

One of the first papers published in *Cereal Chemistry* on the subject of soft-wheat flour was by Patterson (1924), and dealt with the importance of flour particle size in cake flours. He recommended as fine a particle size as was economically feasible. Other work done since then has emphasized that a measure of control should be exercised over cake-flour granulation. It seems likely that the significance of granulation in this case is tied up with the quantity of damaged starch granules present in the flour. The number of these would, of course, be greater in a flour reduced to pass through a bolting cloth with very fine apertures. Alsberg and Griffing (1925) have shown that when the envelopes of starch granules are bruised or broken they take up cold water as fast and to as great an extent as do boiled, undamaged granules. In cake making a foamy structure is built up out of eggs, sugar, and shortening, and then the flour is incorporated with the minimum of mixing to produce a smooth, even batter. A flour such as indicated above, which would combine quickly with the liquids, would require a minimum of mixing time and thus would avoid destruction of the foam structure by overmixing and would have less tendency toward additional water absorption on standing and consequent changing of the batter consistency.

In our laboratory we use a standard Rotap sifter for granulation work. We do not use metal sieves, but use the eight-inch sieve frames and regular mill bolting cloths. Our procedure on soft-wheat flours is as follows: We nest three sieves, 10 XX, 12 XX, and 14 XX, and place 100 grams of the flour on the top sieve, and Carmichael cloth cleaners on each sieve. The sifter is run five minutes, then stopped. The sieves

are carefully dissembled and tapped to remove flour from around the edges and from the tops of the cleaners, with care taken not to lose any of the flour. The sieves are re-assembled and returned to the sifter, which is run for an additional ten minutes. The portions on each sieve and through the 14 XX are then weighed and calculated to percentages. It is our experience that results can be checked within about 2% after the technique is developed. The flour moisture content is a factor, of course, but not as great as would be expected. The interrupted sifting operation was found necessary because of the sticky nature of most soft-wheat flours. It would not be as necessary on more granular flours. We recommend round sieves for this work because they have no corners for the flour to lodge in, and good cloth cleaners are also quite important.

We have heard the comment that this sifting test differs from the bolting action of the commercial flour mill, but what we want is a comparative test for granulation size, and this method has proved serviceable. It lends itself to the control of mill-stream granulation, finding leaks in mill machines, controlling uniformity of bolting, and the comparison of finished flours. Most of the better cake flours will bolt 98% or more through the 14 XX cloth by the method mentioned. We do not use a cloth finer than 14 XX because baking tests do not show that it is necessary. However, when the flour granulation was much coarser than this "98% through the 14 XX," there were definite indications of lowered cake-making quality. We have done little work concerning the significance of granulation in bread and biscuit flours, but we believe that the more granular type of soft-wheat flours, containing fewer damaged starch cells and capable of withstanding more punishment in mixing, would be preferable.

In soft-wheat flours, just as in the hard-wheat, protein quantity and quality, absorption capacity, the various phases of gluten character, and the machines for testing them are to be considered in one group.

A physical test which has been utilized, and which has been under discussion for years, is the viscosity test. Many factors may influence viscosity readings, such as the mineral content of the flour, nature and rate of bleaching, and quantity and quality of gluten, but in general the higher readings indicate greater hydration capacity, greater gluten "strength," and higher grade of flour. In addition to furnishing a picture of the gluten character, the A.A.C.C. viscosity test also permits the plotting of a curve based on viscosity increases as against increments of added lactic acid. The shape of this curve will indicate the manner in which the flour is buffered, and hence the probable grade. One type of viscosity test eliminates the effect of quantity of protein by using an amount of flour in each case equivalent to exactly two grams of protein. Bayfield (1936) has shown that the variations in the bulk of flour used

in this test had but little effect on the viscosity readings. The most generally used type of test, and the one discussed in connection with the addition of increments of acid, uses 20 grams of the flour (15% moisture basis), and does not consider varying percentages of protein.

The biscuit and cracker industries place a high value on the viscosity test, and most such concerns buy flour under rigid specifications for viscosity. Cake flours are not usually purchased under viscosity requirements, but they might well be, with an advantage to the purchaser. Tests conducted with the MacMichael viscosimeter, a torsion-type instrument, are usually specified for flour measurements. In addition to following the grade of flour, viscosity readings appear to be closely connected to wheat variety and growing section. In the Michigan-Ohio district the readings on similar grades of flour will run approximately half as high on the soft white winters as on the soft red winters. This differential may be made quite useful when viscosity specifications fall somewhere between the average viscosities of the two types, and the wheat mixture can be used very nicely to control the viscosity.

Recording dough mixers such as the Brabender farinograph and the Swanson recording mixer can also be adapted for testing soft-wheat doughs. Unless the mixer speeds are slowed down, however, the soft-wheat dough will break down too rapidly to allow formation of a readable curve. In our laboratory we have a Brabender farinograph with a slow-speed mixer for soft-wheat flours and a high-speed mixer for hard-wheat flours. This apparatus has been found useful for determining the speed of dough development, capacity for taking punishment, comparative dough elasticity, and water absorption, and also for recording a permanent record of these determinations. More care is required in a mixer test of a soft-wheat than of a hard-wheat flour on the farinograph. Usually the dough will start to break soon after it has formed, and absorption determinations by the addition of increments of water are difficult.

The specialized soft-wheat flours, which are usually required to be nicely balanced, depend quite a bit on the gluten quantity-quality ratio, with the greater emphasis on gluten quality. Angel-food cake flours seem to do best with a small percentage of firm, elastic gluten. Other cakes require flour with a larger percentage of soft, spongy gluten. Cookies require a flour with a small quantity of somewhat short gluten. Cracker sponge and pretzel flours should run high in quantity and strength of gluten, and so should most flours to be used for hot breads and biscuits and for yeast breads. Flour gluten is probably the most important single factor in the determination of soft-wheat flour character.

Soft-wheat laboratory tests should be confirmed, if possible, by a

scientific baking method adapted to the flour under consideration. The official A.A.C.C. bread-baking test (pup loaf) is being used with excellent results to check and classify flours used in the biscuit and cracker bakeries. This test has also been used to test cake and pastry flours, but in the judgment of the writer it does not give the proper picture here, and is likely to be misleading. Cracker sponge and dough flours are fermented like bread doughs, but cake flours are handled entirely differently, and cake flours must meet conditions not checked by a bread-baking test.

A standard cake-baking test is difficult to develop because there are a number of distinct types of cake-making procedures, all differing in formula and mixing methods. However, an experienced operator can get a good idea of the general possibilities of a cake flour by judging its performance in a layer and loaf formula. Sponge-cake tests seem better suited to test flours for sponge and angel-food cakes because a very small amount of flour is used in an angel-food batter in connection with a large percentage of egg whites, and the quality of the egg whites and the way they are beaten is a more important consideration than a small variation in flour quality. In recent years the sugar and shortener tolerance of cake flours has been increasingly important with the use of richer commercial formulas. Shortener tolerance is allied with gluten strength, with the greater gluten strength requiring increased amounts of shortening. The manner in which sugar tolerance is tied up with granulation, hydrogen-ion concentration, and absorption has already been discussed.

A simplified commercial cookie test was suggested by the writer (Alexander, 1933) and has been used, with few modifications, since then. This test is of value for testing cookie and pie flours and other flours to be used in products which are prepared from doughs in which the gluten is not too fully developed. In this test the symmetry of the cookie, the spread, top grain, internal structure, and thickness are scored and recorded; and a factor based on cookie diameter divided by cookie thickness is used.

The biscuit-baking test is used to evaluate most of the plain, phosphated, or self-rising flours going into the southeastern states for use in the hot breads favored there. This test is the result of years of committee work in the A.A.C.C. In the opinion of the writer, all of the baking tests developed by the A.A.C.C. committees are quite serviceable, although some of them are still tentative tests and will be further improved before being made official.

Proper and uniform scoring is a very important part of all test bakes and this comes only from experience. It is agreed that there are good possibilities of improving our scoring charts so as to make them

more suitable for the use of operators lacking in experience. There are two viewpoints from the standpoint of scoring test bakes. The mill chemist is inclined to look backward through the milling and bleaching processes toward the wheat mixture and the bakery chemist looks forward through the bakery formula and mixing procedure toward the finished bread, but the same kind of baking test should suffice for both.

In this rather lengthy paper we have touched on many of the problems and methods of the flour-mill chemist, but by no means all of them. Those in other lines of work, who still think of flour milling as in the grist mill era, often ask, " What does a chemist find to do around a flour mill? " The correct answer to this query is, " Plenty."

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WHEAT IMPROVEMENT IN THE EASTERN UNITED STATES

B. B. Bayles and J. W. Taylor

Division of Cereal Crops and Diseases, Bureau of Plant Industry,
U. S. Department of Agriculture, Washington, D. C.

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The wheat-improvement program in the eastern United States is of direct interest to the cereal chemist because of its effect on quality of the grain marketed. If the plant breeders and others interested in the wheat-improvement program carefully analyze all the needs of the trade, it should be possible to raise the quality of grain produced as well as reduce the losses to farmers caused by winterkilling, diseases, insects, and other hazards. One of the causes of variability in wheat marketed is the large number of varieties now grown. There are good reasons to believe that the number of varieties in the soft-wheat region in the eastern United States could be limited to a dozen without reducing the total production in this region. This certainly would be the case if the plant breeders were to add, as can be done by more extensive use of backcrossing, more winterhardiness and resistance or tolerance to leaf rust, stem rust, loose smut, stinking smut, Hessian fly, etc., to

selected varieties of soft red winter wheat. The purpose of this discussion is to give some idea of the distribution of varieties in this region, of losses due to specific crop hazards, and the possibility of reducing these losses through plant breeding.

Distribution of Classes and Varieties

Over a period of years, farmers will learn by experience which varieties give the best returns in their locality. If we consider the varieties which have been available for several years, a study of their distribution should indicate rather accurately the types that are best adapted. Varieties may be grown by a few farmers after they have been discarded by most, but a variety or type that is grown on a high proportion of the acreage over a wide area must be well adapted. It is these widely adapted types that should be used as a basis for the wheat improvement program. The latest distribution data available are based on the 1934 crop. Figure 1 shows the approximate distribution of the

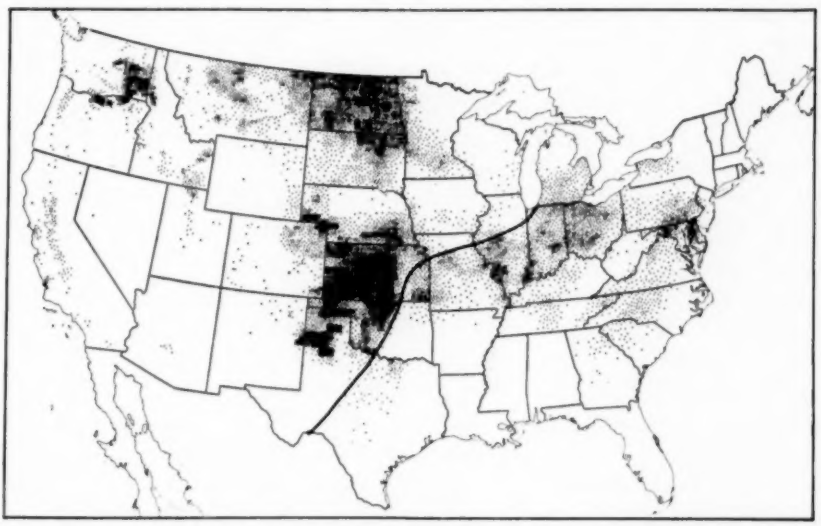

Fig. 1. Distribution of all wheat in the United States in 1934. Soft wheat is the principal kind grown east of the heavy black line. Eact dot represents 5,000 acres.

total wheat acreage in the United States in 1934.[1] Soft red varieties were grown on about 12,750,000 acres and are the predominating class grown east of the heavy line on the map. They constituted practically all of the wheat grown in the region extending as far west as eastern Kansas, with the exception of some hard red winter wheat in central Illinois and some soft white winter wheat in western New York and in Michigan. Twenty-one varieties of soft red winter wheat were grown

[1] For more complete information on the distribution of varieties the reader is referred to U. S. Dept. of Agr. Circ. 424.

on more than 150,000 acres each and 52 varieties on smaller acreages, many of them on only a few hundred acres. Soft white winter varieties were grown on about 710,000 acres in the eastern states. Only two varieties of this class were grown on more than 150,000 acres each, and eight additional varieties on smaller acreages. The estimated acreages for those soft red winter and white winter varieties grown on more than 150,000 acres each are given in Table I. If the acreages of very

TABLE I

VARIETIES OF SOFT RED WINTER AND WHITE WHEATS GROWN IN THE EASTERN UNITED STATES ON MORE THAN 150,000 ACRES EACH IN 1934 [1]

Type or variety	Acreage of	
	Variety	Type or variety
	1,000 acres	*1,000 acres*
RED GRAIN		
Fultz type	—	3,544
Fultz	1,870	—
Trumbull	1,136	—
Fulhio	534	—
Ashland	4	—
Fulcaster type	—	1,910
Fulcaster	1,395	—
Nittany	409	—
V.P.I. 131	106	—
Red May	—	977
Mediterranean type	—	788
Mediterranean	519	—
Red Rock	220	—
Denton	49	—
Leap	—	709
Poole type	—	686
Poole	673	—
V.P.I. 112	13	—
Purplestraw type	—	597
Purplestraw	306	—
Flint	178	—
Redhart	112	—
Gasta	1	—
Currell	—	480
Harvest Queen	—	380
Red Wave	—	307
Purkof	—	300
Forward	—	258
Rudy	—	212
Nigger	—	152
WHITE GRAIN		
Dawson type	—	425
Dawson	356	—
Honor	69	—
Goldcoin	—	243
Total		11,968

[1] Fifty-two other varieties of soft red winter and 8 varieties of soft white winter wheat were grown on less than 150,000 acres each or a total of about 782,000 acres.

similar varieties such as Fultz and the closely related varieties Trumbull, Fulhio, and Ashland that were selected from Fultz are combined, it is found that the Fultz type was grown on about 3,500,000 acres in 1934, concentrated in the area just north of the Ohio river.

The Fulcaster type, including Nittany and V.P.I. 131, was grown on nearly two million acres. This acreage extends throughout the Piedmont section from Pennsylvania, Delaware, and Maryland to Georgia. Rather concentrated areas are also found in central Tennessee, southeastern Kansas, western Missouri, and central Oklahoma.

Red May, commonly known as Michigan Amber in Indiana and Michigan Wonder in Missouri, was grown on nearly a million acres, mostly in Indiana and Missouri. The Mediterranean type, including Red Rock and Denton, was grown on about 750,000 acres. Red Rock is limited chiefly to Michigan and Denton to Texas.

Leap was grown on about 700,000 acres, mostly in the Piedmont from Pennsylvania and New Jersey to North Carolina. The Poole type was grown on about 700,000 acres, mostly in Ohio, Indiana, Kentucky, and Missouri. The Purplestraw type was grown on about 600,000 acres in Virginia, the Carolinas, Georgia, and Tennessee. Currell was grown on about 480,000 acres and Harvest Queen on 380,000 acres, mostly in eastern Kansas, Oklahoma, and Missouri.

About 300,000 acres of Red Wave were grown over a wide area. The 300,000 acres of Purkof were mostly in Indiana and Illinois. The 250,000 acres of Forward were scattered from New York to North Carolina, with the only concentrated area in southeastern Pennsylvania. The 200,000 acres of Rudy were mostly in Indiana. The 150,000 acres of Nigger were in Ohio and Indiana with a few thousand acres in southeastern Kansas.

Only two white wheats are of importance in the eastern states The Dawson type, including Dawson and Honor, was grown on 425,000 acres, mostly in Michigan and New York; and Goldcoin on 243,000 acres, mostly in New York, northern Ohio, and Michigan.

Many of the 52 varieties of soft red winter and 8 of soft white winter grown on less than 150,000 acres each, or a total of about 782,000 acres, could profitably be replaced by better varieties.

Causes of Loss and Their Control

Farmers are going to grow the varieties that they believe will give them the greatest profit. This profit is determined chiefly by the acre yield and the price received for the grain. They are not concerned with quality except as it is reflected in the price. Acre yield is determined by a number of factors such as soil fertility and moisture, as well as by characteristics of the plant itself. The present discussion

is concerned only with the plant characteristics that determine the relative yields and quality of varieties in the wehat-growing areas. An attempt will be made to give some idea of (1) the important factors that cause heavy losses and the areas where these losses occur, (2) differences in varieties with respect to the particular characteristics, and (3) the progress that can be expected in improving standard varieties with respect to some of these characteristics.

Winterkilling

The losses caused by winterkilling in the soft red winter region are probably greater than the combined losses from all plant diseases. The acreage abandoned in the year 1928 when very heavy killing occurred and the average percentage of the acreage abandoned for the years 1909 to 1937 are shown by states in Table II. While no reliable

TABLE II

PERCENTAGE OF ACREAGE OF WINTER WHEAT ABANDONED BEFORE HARVEST [1]

State	Acreage abandoned	
	1928	1909–1937
	%	%
Illinois	62.0	10.9
Indiana	60.0	9.3
Ohio	64.0	9.1
Kentucky	65.0	9.2
Missouri	32.0	7.9
Arkansas	30.4	8.6
Tennessee	28.1	6.2
Georgia	14.5	7.9
South Carolina	11.5	5.2
North Carolina	7.0	3.0
West Virginia	15.1	3.3
Virginia	6.0	2.4
Maryland	2.9	2.6
Delaware	0.9	2.9
New Jersey	5.2	3.8
Pennsylvania	9.0	2.9
Michigan	10.0	4.7
New York	6.1	3.7

[1] Data for 1909–34 compiled from "Revised Estimates of Wheat Acreage, Yield, and Production 1866–1934," September, 1934, reissued May, 1937, mimeographed report of the Bureau of Agricultural Economics; data for 1935–37 compiled from unpublished records of the Bureau of Agricultural Economics.

estimates of acreage abandonment assignable to specific causes are available, it is believed that most of that recorded in Table II was due to winterkilling. Average abandonment in Illinois, Indiana, Ohio, and

Kentucky has been about 10%. Over 60% of the acreage of each of these four states, which grow about half of the soft red wheat crop, was abandoned following the severe killing in 1928. Missouri, Arkansas, Georgia, and Tennessee have a slightly lower abandonment, averaging about 7.5%. The average abandonment in the area east of the Allegheny Mountains is less than 5% in every state except South Carolina, where it is 5.2%. It is also interesting to note the abandonment of only 4.7% in Michigan and 3.7% in New York. Apparently the greater protection of the snow cover and more continuous low temperatures during the winter account for the better survival in these two states, as the varieties are known to be less hardy than those grown in Ohio, Indiana, and Illinois.

It is a well-known fact that wheat varieties differ greatly in their resistance to winterkilling. It is also well known that the plants may be killed either by low temperature or heaving, or a combination of the two, and by other environmental conditions. In the Great Plains drought also causes heavy abandonment, but in the soft red winter region this seldom is a factor and the difference between the seeded and harvested acreages is caused primarily by winterkilling from low temperature and heaving. Results from an extensive series of experimental tests during the years from 1933 to 1937 indicate that low temperature may have been the more important cause of killing during this period, although heaving is considered to have been the chief cause of killing in the soft red winter region previous to this time. In these tests, 30 varieties have been grown under comparable conditions at about 25 locations in the eastern soft wheat area in each of the last five years, making a total of about 125 tests. In 34 of them, partial killing of medium-hardy varieties was attributed mainly to low temperature. The reports indicate that in only four tests has killing been caused by heaving. Little or no killing has occurred in 87 of the tests. It may be that these tests have not been continued long enough or for other reasons do not properly represent the conditions in this area, and it is also likely that heaving, although not apparent, has contributed to injury by low temperature.

A summary of the results from those tests in which differential killing occurred is presented in Table III. In the tests where low temperature was the chief cause of killing, Minhardi, Minturki, Wisconsin Pedigree No. 2, and Illinois No. 2 had average survivals of over 80%, whereas Leap and Purplestraw averaged only 25.5% and 32.4% survival. The varieties Red May, Fulhio, Trumbull, Poole, and Rudy, which are commonly grown in Ohio, Indiana, and Illinois, averaged only 70.3, 65.1, 64.9, 60.1, and 57.7% respectively.

Purkof, which averaged 79.8% survival, probably owes much of its

TABLE III

SURVIVAL OF VARIETIES IN THE EASTERN NURSERIES WHERE DIFFERENTIAL KILLING WAS CAUSED CHIEFLY BY LOW TEMPERATURE AND BY HEAVING, 1933 TO 1937[1]

Variety and C.I. No.[2]	Low temperature		Heaving	
	Av. 34 station years	Rank	Av. 4 station years	Rank
	%		%	
Minhardi (5149)	85.6	1	46.4	27
Minturki (6155)	82.4	2	49.9	26
Wisconsin Pedigree No. 2 (6683)	80.6	3	—	—
Illinois No. 2 (11537)	80.6	3	72.0	12
Purkof (8381)	79.8	5	60.1	24
Kawvale (8180)	77.6	6	73.9	8
Kharkof (1442)	75.9	7	45.8	28
Harvest Queen (6199)	72.1	8	65.5	20
Red May (Michigan Amber) (5620)	70.3	9	70.8	16
Baldrock (11538)	69.3	10	86.1	1
Purdue No. 1 (11380)	67.6	11	83.4	2
Mediterranean selection (11567)	65.9	12	73.6	9
Fulhio (6999)	65.1	13	72.8	10
Trumbull (5657)	64.9	14	71.3	14
Fulcaster (6471)	63.5	15	78.5	5
Poole (3488)	60.1	16	71.0	15
Goldcoin (Junior No. 6) (6971)	57.9	17	56.8	25
Nabob (8869)	57.7	18	80.5	4
Rudy (5656)	57.7	18	83.0	3
Forward (6691)	57.4	20	70.8	16
Nittany (6962)	57.1	21	69.1	18
Gladden (5644)	56.5	22	74.6	6
Dawson (American Banner) (6943)	56.4	23	62.7	23
Valprize (11539)	55.7	24	64.3	22
Currell (3326)	55.5	25	72.1	11
Honor (6161)	54.4	26	68.5	19
Red Rock (6951)	53.1	27	74.5	7
Purplestraw (1915)	32.4	28	71.7	13
Leap (6958)	25.5	29	64.6	21
Redhart No. 2 (11654)	5.1[3]	—	—	—

[1] Uniform nurseries maintained by the Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture, in cooperation with the State agricultural experiment stations in the soft red winter wheat region.

[2] Accession number of the Division of Cereal Crops and Diseases, formerly Office of Cereal Investigations.

[3] Average of 31 station years. Leap for same years was 23.0.

productiveness and popularity to its hardiness. It is interesting to note that Goldcoin (Junior No. 6), Forward, Dawson (American Banner), Valprize, Honor, and Red Rock, the chief varieties grown in Michigan and New York, all average less than 60% survival, yet as shown in Table II the average killing in these two states is less than in states to the south.

In the four tests where heaving was the main cause of killing, Minturki and Minhardi ranked 26th and 27th among 28 varieties in average survival, whereas they had ranked second and first in those tests where low temperature was the chief cause of killing. On the other hand, Red Rock and Gladden, which ranked 27th and 22nd in the tests where killing was caused by low temperature, ranked sixth and seventh where killing was due to heaving.

It is encouraging, however, to note that some varieties had a good survival where both types of killing occurred. Among these were Illinois No. 2, Kawvale, Baldrock, and Purdue No. 1, four varieties of comparatively recent origin, which shows that it is possible to obtain types by breeding that will combine a relatively high degree of resistance to both types of killing. In addition, Baldrock, Purdue No. 1, and Illinois No. 2 produce typical soft grain.

The greatest need in breeding for winterhardiness is some practical method of measuring the resistance to heaving. It was mentioned earlier that of about 125 tests in the field, information on the resistance of the varieties to heaving was obtained in only four. These were at Ithaca, N. Y., Kearneysville, W. Va., and Columbia, Mo., in 1933, and Elsberry, Mo., in 1937. It is possible that after careful study fields may be selected for heaving tests in areas where soil type and alternate freezing and thawing are more conducive to heaving so that differential killing may be encountered more often. It has been possible to obtain reliable information on resistance of varieties to low temperatures both in field tests and with controlled temperature cabinets, but as yet a satisfactory technique has not been devised for determining, with controlled equipment, the relative resistance to heaving.

Hessian Fly

A better understanding of the factors that influence winterkilling in the central states leads some to believe that delayed seeding to control the Hessian fly is responsible for a considerable amount of winter injury. If every farmer could seed during the few days of the recommended period, the loss from delayed seeding would probably be slight. However, rain or the pressure of other farm operations often causes further delay in seeding, and the late-sown wheat plants may not be firmly established before winter sets in. This is especially true on heavy wet soils subject to winterkilling by heaving. If adapted varieties resistant to the Hessian fly were available, the hazard of too-late seeding would be lessened.

It has long been known that some varieties were injured less than others by fly but none was sufficiently resistant to escape serious loss under heavy infestation. Recent studies, however, have uncovered

some varieties that are highly resistant; and while they are not of value as commercial wheats, experiments have shown that the factors for resistance can be transferred to commercial varieties by hybridization. As shown in Table IV, the durum variety F.P.I. 94587 [2] has been very

TABLE IV

REACTION OF WHEAT VARIETIES TO HESSIAN FLY, 1936–37 [1]

(Percentages of plants infested)

Variety	Bird's Landing, Calif.	Junction City, Kansas	Springfield, Missouri		La Fayette, Indiana	
	Spring	Fall	Fall	Spring	Fall	Spring
Durum (F.P.I. 94587)	0	0	3	—	0	—
Illinois No. 1W38	9	8	3	—	1	—
Dawson (C.I. 3342)	0	40	42	92	72	63
Red May (Michigan Amber)	7	51	59	83	79	48
Nittany (C.I. 6962)	98	70	42	96	66	47

[1] Cooperative investigations of the Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine, and the Division of Cereal Crops and Diseases, Bureau of Plant Industry, and the agricultural experiment stations of Indiana, Missouri, Kansas, and California.

highly resistant to Hessian fly under all conditions. Illinois No. 1W38 has also been resistant in all tests. Dawson and Red May, on the other hand, have been very resistant in California and susceptible elsewhere. Nittany has been susceptible in all tests. Dawson has remained free or nearly free under heavy infestations in the Montezuma Hills section of California for several years. The commercial varieties in this area are Big Club and Poso. New lines have been obtained by hybridization that are very similar to these varieties but which are as resistant as Dawson to Hessian fly. Studies under way at La Fayette, Ind., also have demonstrated that the resistance of the durum variety F.P.I. 94587 [3] can be transferred by hybridization to soft-wheat types, and it seems likely that adapted types that approach the better soft wheats in quality of grain can be produced by backcrossing.

Lodging

The losses due to lodging are difficult to estimate but are unquestionably heavy in the more humid areas in certain years. Lodging may cause a reduction in both yield and quality, especially if it occurs soon after heading. The yield is reduced by shriveling of the grain because of inability of the leaves to efficiently manufacture food when the plants are down and receive less sunlight. Cases have been observed where the weight of grain was reduced more than one-third.

[2] Accession number of the Division of Plant Exploration and Introduction, formerly Office of Foreign Plant Introduction.

[3] See footnote 2.

Diseases such as leaf and stem rust, mildew, and leaf and glume blotch also are very destructive in lodged grain. The quality of grain from fields that are badly lodged is often injured by diseases, weathering, and sprouting.

Most of the commercial soft red winter varieties have fairly stiff straw but many are rather tall and are excelled in resistance to lodging by some of the newer varieties such as Valprize. It should be possible to introduce more resistance to lodging into the soft red varieties and thus reduce the losses due to lower yield and quality.

Leaf and Stem Rust

The rusts have for centuries taken an intermittently heavy toll from the wheat crop. Estimates of the combined losses from leaf and stem rust in the states growing mostly soft red winter wheat are given in Table V for the years 1935 and 1937, when severe epidemics oc-

TABLE V

ESTIMATED LOSSES FROM RUST IN BUSHELS AND IN PERCENTAGES IN THE STATES PRODUCING CHIEFLY SOFT RED WINTER WHEATS, 1909–37 [1]

State	1935		1937		Average 1909–1937	
	1,000 bushels	Per-centage	1,000 bushels	Per-centage	1,000 bushels	Per-centage
Missouri	2,418	10.0	17,660	30.0	2,944	10.7
Illinois	1,567	5.0	9,613	16.0	1,844	5.4
Ohio	2,120	5.0	3,553	7.0	2,169	5.1
Indiana	320	1.0	9,920	22.0	651	1.7
Michigan	964	5.0	1,572	3.0	985	4.9
Virginia	271	3.0	270	2.5	271	3.0
Tennessee	0	0.0	780	10.0	27	0.3
North Carolina	0	0.0	485	7.0	17	0.2
Kentucky	0	0.0	549	5.0	19	0.2
Pennsylvania	0	0.0	4,622	12.3	159	0.4
Maryland	0	0.0	97	1.0	3	T
West Virginia	5	0.2	0	0.0	5	0.2
New York	0	0.0	2,340	20.5	81	0.7
Delaware	0	0.0	0	0.0	0	0.0
New Jersey	0	0.0	0	0.0	0	0.0
South Carolina	—	—	0	0.0	—	—
Georgia	—	—	638	30.0	—	—

[1] Data compiled from the records of the Plant Disease Survey, Mycology and Disease Survey, Bureau of Plant Industry.

curred, and the average for the period from 1909 to 1937. It will be noted that, while the average losses have not been very high, the losses in some years and in certain areas have been heavy.

The heaviest losses in the soft red winter region in most years are caused by leaf rust, but in 1937 the loss from stem rust was heavy in some states. Stem rust losses were estimated at 30% in Missouri,

12% in Indiana, 8% in Tennessee, 2% in Ohio, 2.5% in Michigan, and 2% in Virginia. The losses from leaf rust in 1937 were heaviest in New York, Pennsylvania, North Carolina, Illinois, and Ohio. Both rusts cause such heavy losses that breeding for resistance should be included in a well-rounded improvement program.

Breeding for resistance to stem and leaf rust has progressed much farther in the hard red spring wheats than in the winter wheats. Thatcher, which has been commercially grown since 1934, suffered very little loss in the severe stem rust epidemics of 1935 and 1937, and other new hard red spring hybrids not yet distributed are even more resistant to stem rust than is Thatcher, and are also resistant to leaf rust. Marked differences in resistance to leaf and stem rusts are found in the winter wheats. Results for some varieties grown in uniform rust nurseries at a number of locations in 1935, 1936, and 1937 are shown in Table VI. A number of new hybrids and selections are

TABLE VI

REACTION OF WHEAT VARIETIES TO LEAF AND STEM RUST IN THE UNIFORM NURSERIES, 1935–37 [1]

(Average infection coefficients)

Variety or cross and C.I. No.	Leaf rust			Stem rust		
	1935, 18 nurseries	1936, 13 nurseries	1937, 10 nurseries	1935, 4 nurseries	1936, 6 nurseries	1937, 8 nurseries
Minhardi (5149)	81	55	57	42	55	59
Minturki (6155)	74	42	58	20	30	33
Mediterranean (3332)	59	38	39	76	56	72
Mediterranean selection (11587)	19	9	9	75	55	73
Kawvale x Tenmarq (11669)	—	14	12	—	27	29
Kawvale x Tenmarq (11750)	—	4	11	—	30	30
Hard Federation x Kawvale (11753)	—	2	6	—	31	51
Fulcaster x Tenmarq (11751)	—	2	5	—	31	40
Wabash (11384)	5	1	3	55	55	54
Hope x Hussar (11682)	1	1	1	1	2	T
Hussar (4843)	36	31	30	46	48	63
Mediterranean x Hope (11763)	—	—	4	—	—	4

[1] Data for 1935 and 1936 compiled from "Report of the Cooperative Uniform Cereal-Rust Observation Nurseries for the Year 1935," Jan. 15, 1937, and "Report of the Cooperative Uniform Cereal-Rust Observation Nurseries for the Year 1936," June 28, 1937, U. S. Dept. Agr., Bur. Plant Indus., Div. Cereal Crops and Diseases (Unnumb. Pub., Mimeographed). Data for 1937 compiled from notes taken by H. B. Humphrey, M. N. Levine, E. C. Stakman, C. O. Johnston, R. M. Caldwell, W. M. Bever, and H. C. Murphy.

highly resistant to leaf rust and somewhat resistant to stem rust. Those of most interest are Hope x Hussar (C.I. 11682) and Mediterranean x Hope (C.I. 11763). These two winter varieties received their resistance from the Hope parent and have been highly resistant to both leaf and stem rust. They are not suitable for commercial pro-

duction, however. The next step in the breeding program was to cross them with the commercial types of soft red wheat. From these crosses made at La Fayette, Ind., Manhattan, Kans., and College Station, Tex., lines are being selected that retain resistance to both leaf and stem rusts and that have grain and plant characters more nearly like the commercial parents. Wabash, which is highly resistant to leaf rust, is being recommended in Indiana and Illinois.

Loose Smut

The average estimated reduction in yield caused by loose smut for the eastern states for the period from 1917 to 1936 is shown in Table VII. The heaviest losses occurred in the Piedmont and moun-

TABLE VII

AVERAGE ESTIMATED REDUCTION IN YIELD CAUSED BY LOOSE SMUT IN THE EASTERN STATES, 1917 TO 1936 [1]

State	Reduction in yield	State	Reduction in yield
	%		%
Virginia	2.6	Missouri	1.7
West Virginia	2.6	Indiana	1.7
Pennsylvania	2.4	Texas	1.5
Georgia	2.4	Oklahoma	1.4
Arkansas	2.4	New Jersey	1.4
Maryland	2.2	Illinois	1.3
Kentucky	2.1	Ohio	1.3
North Carolina	2.0	New York	1.2
Michigan	1.8	Tennessee	1.1
South Carolina	1.7	Delaware	0.7

[1] Data from records of Plant Disease Survey, Mycology and Disease Survey, Bureau of Plant Industry.

tainous areas in Virginia, West Virginia, Pennsylvania, Georgia, Maryland, North Carolina, and Kentucky, which have had estimated average losses of from 2 to 2.6%. Losses in the other soft red winter states are estimated at from 1 to 2%, with the exception of Delaware, where they have been lower. Losses have been estimated as high as 5% for some years in some states, and individual fields have been observed with more than 30% of the heads smutted. Breeding for resistance to loose smut has been given little consideration largely because a satisfactory method of testing for resistance has not been developed. Recently, however, methods of inoculating the flowers have been improved and more work is being done on this problem.

It has been shown that there are several races or varieties of loose smut and until more survey work has been done to check the races commonly present in the wheat-growing areas the value of resistant varieties cannot be predicted definitely. However, varieties are

available as parents for crossing which have not been infected with any collection of smut to which they have been subjected.

The reaction of the more resistant of a large number of varieties tested in the years from 1923 to 1928 is shown in Table VIII, together

TABLE VIII

PERCENTAGE OF SMUTTED HEADS IN VARIETIES OF WINTER WHEAT WHEN HAND-INOCULATED WITH LOOSE SMUT [1]

Class and variety and C.I. No.	Years tested	Total heads	Smutted heads
	No.	*No.*	*%*
Soft Red Winter:			
Forward (6691)	3	946	0.0
Fulcaster (3605)	3	658	0.5
Leap (4823)	3	1,873	1.1
Purplestraw (1915)	3	867	0.9
Sol (6009)	2	1,398	0.0
Trumbull (5657)	2	449	0.0
Red Rock (5976)	2	928	24.0
Hard Red Winter:			
Blackhull (6251)	3	434	0.0
Hussar (4843)	2	1,764	0.4
Ridit (6703)	2	1,443	0.0
Turkey (1558)	1	775	46.4

[1] V. F. Tapke, Influence of varietal resistance, sap acidity, and certain environmental factors on the occurrence of loose smut in wheat, J. Agr. Research **39**: 313–339, Sept. 1, 1929.

with the infection in two susceptible varieties. Several soft red winter varieties including Forward, Leap, Trumbull, and Purplestraw were highly resistant. To inoculum used in 1937 they were, however, susceptible. Kawvale and Illinois No. 2, not included in the earlier tests, were resistant. It seems likely that the inoculum used in the later experiments contained additional races. If these two varieties continue to be resistant to other races, it should be comparatively easy to get resistance into the commercial soft red winter varieties by hybridization. The hard red spring variety Hope has been inoculated with several races and has been very resistant in all tests.

Bunt, or Stinking Smut

The percentages of soft red winter wheat receipts at the terminal markets in the years from 1928 to 1936 that were graded smutty are shown in Table IX. These data are compiled from the grain inspection records of the Grain Division of the Bureau of Agricultural Economics. By far the heaviest losses occurred in Maryland and Pennsylvania, where averages of 22.0% and 14.6%, respectively, of the wheat received at inspection points were graded smutty. In the important soft red winter states, Michigan, Ohio, and Indiana, 2% or more of

the receipts graded smutty, and in several other states more than 1% graded smutty. Of all soft red winter receipts, except at the Pacific Northwest terminals, 3.2% graded smutty.

TABLE IX

SUMMARY OF CARS OF SOFT RED WINTER WHEAT WHICH GRADED SMUTTY WHEN INSPECTED AT TERMINAL MARKETS IN THE EASTERN STATES IN THE NINE CROP YEARS, 1928–1936 [1]

States	Cars inspected		
	Total	Graded smutty	
	No.	*No.*	%
Alabama	52	1	2.0
Illinois	27,253	367	1.4
Indiana	40,957	822	2.0
Kansas	15,818	334	2.1[2]
Kentucky	21,553	269	1.2
Louisiana	44	0	0.0
Maryland	17,866	3,935	22.0
Massachusetts	52	3	5.8
Michigan	3,613	85	2.4
Missouri	100,802	1,609	1.6
New York	20,941	278	1.3
Ohio	79,348	1,731	2.2
Oklahoma	2,489	20	0.8
Pennsylvania	8,027	1,174	14.6
Tennessee	9,255	120	1.3
Texas	5,394	58	1.1
Virginia	1,489	28	1.9
Wisconsin	818	16	2.0
Total	339,953	10,850	3.2

[1] Data compiled from grain inspection records of the Grain Division, Bureau of Agricultural Economics.

[2] If 107 cars received at Salina, Kans., in 1935 and 1936 of which 63 were smutty are omitted, this figure becomes 1.7%. Shipments from the Pacific Northwest to Salina were heavy in those years.

Fifteen years ago the problem of breeding smut-resistant wheats seemed comparatively simple. At that time only a single race of stinking smut was known and it was thought that the varieties of wheat that were resistant to it would be safe from infection. Later studies have shown that there are numerous races or varieties of *Tilletia levis* and *T. tritici*, the fungi that cause bunt. The reactions of the varieties that differentiate 19 races are shown in Table X. From these results it may be noted that there are several pairs of varieties that together contain factors for resistance to all known races and it should be possible, theoretically, to cross these varieties and select hybrid lines resistant to all known races. This has already been accomplished. A selection (C.I. 10068−1) from a Hussar x Hohenheimer cross has been inoculated with all the known races and many collections from fields and has never had more than a trace of smut. Selections from a cross between Oro and a Turkey-Florence hybrid,

TABLE X

RELATIVE SUSCEPTIBILITY OF 10 DIFFERENTIAL HOSTS TO 11 PHYSIOLOGIC RACES OF *Tilletia tritici* AND 8 PHYSIOLOGIC RACES OF *T. levis*[1]

(R = 0%–10%; I = 11%–40%; S = 41%–100%)

Physiologic race No.	Hybrid 128 (C.I. 4512)	Ridit (C.I. 6703)	Oro (C.I. 8220)	Hohenheimer (C.I. 11458)	Hussar (C.I. 4843)	Albit (C.I. 8275)	Ulka (C.I. 11478)	Marquis (C.I. 3641)	Canus (C.I. 11637)	Mindum (C.I. 5296)
					Tilletia tritici					
T–1	S	R	R	R	R	R	S	**I**[2]	R	**R**
T–2	S	R	R	R	R	R	S	**R**	R	**S**
T–3	S	**R**	R	R	**R**	**R**	S	S	**S**	**I**
T–4	S	R	R	R	R	**I**	S	S	**R**	**I**
T–5	S	R	R	R	R	**I**	S	S	**S**	**I**
T–6	S	R	R	R	**R**	**S**	S	S	R	**I**
T–7	S	R	R	R	**I**	**S**	S	S	**I**	**I**
T–8	S	R	R	R	**S**	**S**	S	S	S	**I**
T–9	S	R	R	**I**	R	**R**	S	**I**	R	**I**
T–10[3]	S	R	R	**S**	R	**R**	R	**I**	R	**R**
T–11	S	**S**	R	R	R	R	**I**	S	**S**	**I**
					Tilletia levis					
L–1	S	R	R	R	R	R	S	**I**	**R**	**I**
L–2	S	R	R	R	R	R	S	**S**	**R**	**I**
L–3	S	R	R	R	R	R	S	**S**	**S**	**I**
L–4	S	R	R	R	R	**S**	S	**I**	**R**	**I**
L–5	S	R	R	R	**R**	**S**	S	S	**S**	**I**
L–6	S	R	R	R	**I**	**S**	S	S	S	**I**
L–7	S	R	R	R	**S**	**S**	S	**I**	S	**I**
L–8	S	R	**S**	R	R	**R**	S	S	S	**I**

[1] H. A. Rodenhiser and C. S. Holton, Physiologic races of *Tilletia tritici* and *T. levis*, J. Agr. Research *55*: 483–496, Oct. 1, 1937.

[2] Reactions that differentiate physiologic races are indicated by bold-face type.

[3] The reaction of spring wheat differential hosts to this race was obtained in 1936 only. The results are therefore not strictly comparable with those recorded for the other races. The results are included, however, to indicate particularly the resistance of Ulka to race T–10.

which has the same reaction to races as Ridit, have also been highly resistant in all tests thus far made. Inoculum of at least three races, identified after the data in Table X were published, has been included in these tests. Resistance to the 22 known races appears to have been combined in these hybrids. They were developed in the western states and are not adapted for commercial production in the soft red winter region but it should be possible to transfer this resistance to adapted commercial types.

Other Diseases

There are several other diseases that cause appreciable losses only in restricted areas and that should be given consideration in the improvement program for those areas. For example, the mosaic

disease causes heavy losses in some fields in southern Indiana and Illinois. A number of varieties of soft red winter wheat are resistant to this disease, while others are very susceptible. Leaf spot (*Septoria tritici*) and glume blotch (*S. nodorum*) cause heavy losses in some years, especially in the Atlantic Coastal Plains area. Scab has caused heavy losses in some years in the Corn Belt.

Objective of the Breeding Program

The most common evaluation of wheat varieties in the past has been on the basis of yield. There usually are present one or more deleterious factors, such as winterkilling, lack of moisture, the Hessian fly, or one or more diseases such as leaf rust, stem rust, bunt, and loose smut, which reduce the yield. The objective of the wheat-improvement program is to lessen the fluctuation in production from year to year by reducing the toll taken by these crop hazards with respect both to yield and quality. This objective will most readily be attained by breeding into the widely adapted commercial varieties such characteristics as resistance to winterkilling, Hessian fly, lodging, and the various diseases.

THE RELATION BETWEEN PROTEIN CONTENT AND STRENGTH OF GLUTEN-ENRICHED FLOURS[1]

T. R. AITKEN and W. F. GEDDES

Board of Grain Commissioners, Grain Research Laboratory, Winnipeg, Canada

(Read at the Annual Meeting, May 1938)

A review of the literature dealing with the relation between protein content and loaf volume of flours produced from the same class of wheat reveals that many of the investigators have found a non-linear relationship. In the earlier studies, such as those of Bailey (1913), Stockham (1920), Shollenberger (1923), Bailey and Sherwood (1926), the increase in loaf volume per unit increase in protein content diminished until a protein level of from 15% to 16% was reached; in some cases further increases were accompanied by loaf-volume decreases. In the light of the more recent studies of Larmour (1931), Harris (1932) and Geddes and Larmour (1933), demonstrating the greater bromate response of the higher-protein flours, it appears probable that the true relative strengths of such flours, as reflected by loaf volume, were not revealed by the earlier baking methods; such a situation would naturally result in a non-linear regression. In some instances variations in

[1] Published as paper No. 148 of the Associate Committee on Grain Research, National Research Council of Canada and Dominion Department of Agriculture.

the "protein character" of the flours may also have been a factor, especially where flours of varying grade were involved in the comparisons.

The procedure reported by Aitken and Geddes (1937) for preparing dried gluten appeared to provide a means of securing a series of flours of any desired level in protein content without introducing differences in protein character, and the study reported here was undertaken to determine the relation between loaf volume and protein content over a wider range in the latter variable than has been possible heretofore.

Experimental

Since any alteration in the strength-imparting properties of gluten as a result of its preparation would have an important bearing on the loaf volumes obtained with a series of flours containing increments of dried gluten, a preliminary study was undertaken to determine whether such protein-enriched flours gave baking results similar to normal flours of equivalent protein content. For this purpose, three high-grade Canadian hard red spring wheats were composited from envelope samples to yield long patent flours of approximately 12, 14, and 16% protein content; the individual samples in the blends were confined to the first three grades which comprise sound wheat of the Marquis type and were considered to be uniform in protein "quality."

Portions of each flour were employed to prepare powdered dried gluten according to the method described by Aitken and Geddes (1937) with the exception that the Dill and Alsberg (1924) solution was used for washing; the yield of dried gluten ranged between 17 and 22%, depending upon the protein content of the flours. Using the original flours and the dried gluten prepared therefrom, the series of protein-enriched flours listed in Table I was prepared and baked in random order, in comparison with the original flours, by the malt-phosphate-bromate (0.001% $KBrO_3$) formula as outlined by Aitken and Geddes (1934) according to the A. A. C. C. procedure.

The data recorded in Table I show that the absorptions and loaf volumes of the gluten-enriched flours correspond very closely with those of the unenriched original flours of equivalent protein content, and indicate that the process employed for obtaining gluten in a dried fine granular state does not alter its strength-imparting characteristics to any apparent extent. The doughs from the gluten-treated flours were indistinguishable from the original flours of the same protein content as regards spring and general handling quality; also the external and internal characteristics of the loaves were closely similar.

In view of these results, dried gluten was prepared from a low-protein, experimentally milled hard red spring wheat flour; this was

TABLE I

PROTEIN AND LOAF VOLUME DATA

Reference No.	Flour	Protein [1]	Absorption [2]	Loaf volume	Loaf volume per unit protein
		%	%	c.c.	c.c.
A	Original, low protein	11.9	54.9	655	55
B	Original, medium protein	13.8	57.0	728	53
AA_2	A + "A" dried gluten	13.6	—	716	53
AB_2	A + "B" dried gluten	13.9	—	725	52
AC_2	A + "C" dried gluten	13.5	—	716	53
C	Original, high protein	15.7	59.0	774	49
AA_3	A + "A" dried gluten	15.5	58.9	795	51
AB_3	A + "B" dried gluten	15.5	—	786	51
AC_3	A + "C" dried gluten	15.6	59.4	804	52
BA_3	B + "A" dried gluten	15.7	59.2	781	50
BB_3	B + "B" dried gluten	15.7	59.4	816	52
BC_3	B + "C" dried gluten	15.8	59.6	816	52

[1] N × 5.7 on a 13.5% moisture basis. Protein content determined by a modification of the Kjeldahl-Gunning procedure.
[2] Determined by the Brabender farinograph (small mixer) at a dough consistency of 600 units. Results expressed on a 13.5% moisture basis.

added to the original flour in increasing proportions to provide a series of seven samples ranging in protein content from 10.5 to 22.7% in approximately 2% increments. The results of miscellaneous determinations on these flours are recorded in Table II, and it is of interest to note the increase in water-absorption and dough-development time

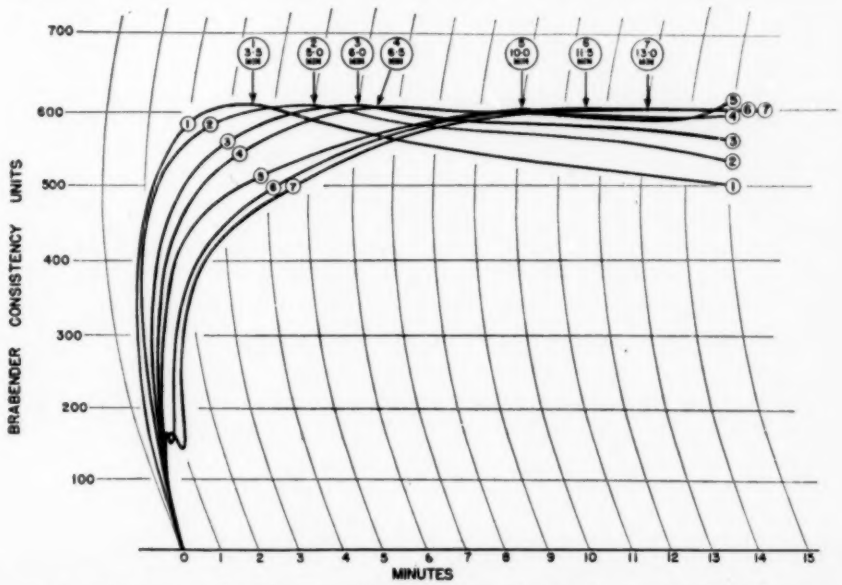

Fig. 1. Farinogram median lines illustrating effect of increasing protein content on type of curve.

with each increment of increase in protein content as revealed by the farinograph data. The changes in curve type are illustrated in Figure 1, in which lines drawn through the middle of the individual farinogram bands are reproduced; curve No. 1 resembles that of a medium-strength flour, while curves 2, 3, and 4 resemble those of strong Canadian Northern wheats; curves 5 and 6 have only rarely been encountered in this laboratory on samples of very high protein content, while No. 7 has never been obtained on a natural flour. These progressive changes in curve characteristics from that of a medium to that of a very strong flour indicate that protein content is an important factor in determining the type of farinogram.

TABLE II

MISCELLANEOUS CHEMICAL AND BRABENDER FARINOGRAPH DATA

Chemical data (13.5% moisture basis)						Brabender farinograph data	
Flour No.	Protein content (N ×5.7)	Ash content	Diastatic activity (maltose per 10 g. flour)	Gassing power (gas from 25 g. flour after 6 hours)	Lipides	Absorption 13.5% M.B. (600 units)	Dough development time
	%	%	*mg.*	*c.c.*	%	%	*min.*
1	10.5	0.53	273	—	1.96	59.7	3.5
2	13.0	0.54	—	558	—	62.3	5.0
3	14.9	0.55	256	—	—	62.7	6.0
4	16.8	0.55	—	520	—	65.1	6.5
5	19.0	0.56	247	—	3.34	66.9	10.0
6	20.7	0.57	—	483	—	68.5	11.5
7	22.7	0.59	234	—	—	70.7	13.0
Dried gluten	64.8	0.75	124	—	9.98	—	—

Ash content determined by the Official A.O.A.C. procedure. Diastatic activity determined by the method outlined by Blish and Sandstedt (Cereal Chem. 10: 189–202, 1933). Gassing power determined as outlined by Bailey and Johnson (Cereal Chem. 1: 293–304, 1924). Lipide content determined as outlined in Cereal Laboratory Methods, 1935, p. 89.

For the purpose of determining comparative baking strength, the flours were baked according to the A. A. C. C. procedure at three levels of diastatic activity and four of potassium bromate, 0.1% $NH_4H_2PO_4$ being added in all cases; in view of the large amount of material which would be required for replicate tests, single loaves were baked by each formula. The estimation of experimental error was made possible by designing an experiment in which protein level was confounded with days; each flour was baked by all twelve formulas on successive days, the baking formulas being randomized.

In addition to determining loaf volume, the loaves were scored for external and internal characteristics. The loaves exhibited a trend from "green" or underfermented to "old" or overfermented character-

istics with increasing increments of bromate which was particularly noticeable in the instance of the low-protein flours.

The loaf-volume results are recorded in Table III and a variance analysis of these data is given in Table IV. Highly significant differences exist between the volumes for different protein levels and bromate treatments but the differences due to malt additions are not significant, indicating that the untreated flour was sufficiently high in diastatic activity (273 units) to eliminate gas production as a factor affecting loaf volume. The highly significant interaction of protein content × bromate level is a reflection of the increased tolerance to bromate with increasing protein content.

TABLE III

LOAF-VOLUME DATA

Flour protein	No malt				0.5% malt			
	No $KBrO_3$ (B_0M_0)	1 mg. $KBrO_3$ (B_1M_0)	2 mg. $KBrO_3$ (B_2M_0)	3 mg. $KBrO_3$ (B_3M_0)	No $KBrO_3$ (B_0M_1)	1 mg. $KBrO_3$ (B_1M_1)	2 mg. $KBrO_3$ (B_2M_1)	3 mg. $KBrO_3$ (B_3M_1)
%	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.
10.5	711	655	552	458	720	716	533	448
13.0	697	706	665	495	711	767	650	533
14.9	762	823	702	543	772	879	669	566
16.8	776	926	781	623	781	940	809	595
19.0	898	1058	922	781	907	1044	879	734
20.7	922	1120	1110	874	988	1166	1039	870
22.7	1091	1269	1297	935	1100	1246	1241	907

Flour protein	1.0% malt				Mean, all malt levels			
	No $KBrO_3$ (B_0M_2)	1 mg. $KBrO_3$ (B_1M_2)	2 mg. $KBrO_3$ (B_2M_2)	3 mg. $KBrO_3$ (B_3M_2)	No $KBrO_3$	1 mg. $KBrO_3$	2 mg. $KBrO_3$	3 mg. $KBrO_3$
%	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.	c.c.
10.5	725	744	557	500	719	715	547	469
13.0	730	748	664	524	713	740	660	517
14.9	804	856	702	557	779	853	691	555
16.8	823	959	800	637	793	942	797	618
19.0	949	1072	898	804	918	1058	900	773
20.7	967	1138	1067	903	959	1141	1072	882
22.7	1072	1260	1119	964	1088	1258	1219	935

The regression coefficients for loaf volume on protein are recorded for each formula in Table V, together with those for the means of all malt treatments combined for each level of bromate; as a measure of the significance of the differences in the regression coefficients, the

TABLE IV

ANALYSIS OF VARIANCE FOR LOAF-VOLUME DATA

Variance due to:	D.F.	Variance	F	5% point
Between bromate levels	3	277164.77	126.9	4.76
Between malt levels	2	1590.08	—	—
Interaction:				
Malts × bromates (error for above)	6	2184.75	4.15	2.36
Between protein levels	6	439432.08	60.68	2.66
Interactions:				
Protein × malts	12	984.30	1.87	2.03
Protein × bromates (error for protein)	18	7241.75	13.77	1.93
Protein × malts × bromates (error for interactions)	36	525.92	—	—
Total	83	—	—	—

results of covariance analyses are also recorded. Significant differences exist between the regression coefficients for the various bromate levels, those for the 0.001% and 0.002% being the highest; an analysis of variance showed that these two regressions are not significantly different. The regressions for the combined volumes of all malt levels for each bromate treatment are shown graphically in Figure 2. While

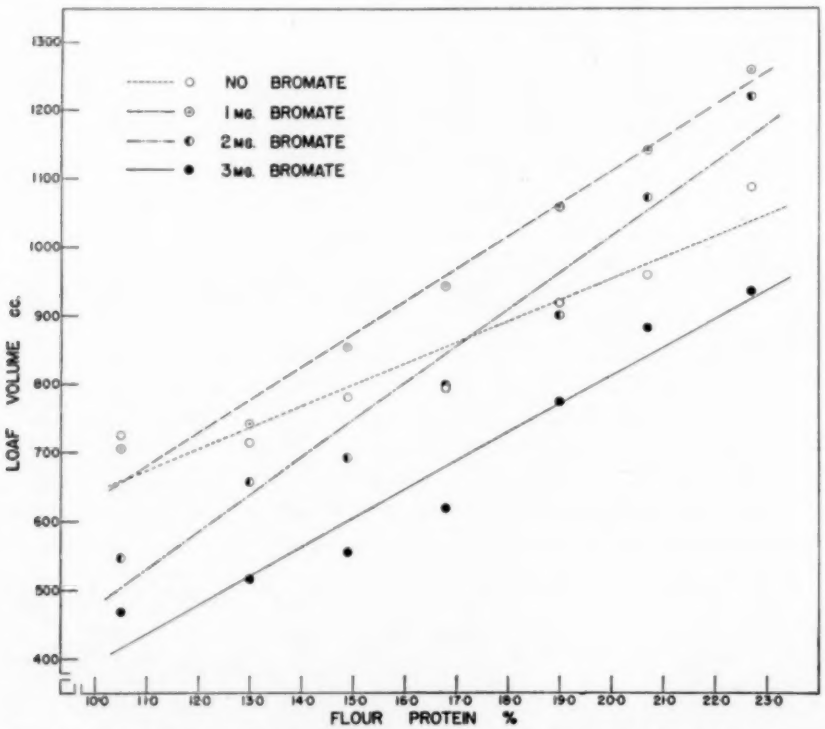

Fig. 2. Regression of loaf volume on flour protein as influenced by potassium bromate content.

there are insufficient data to permit an accurate test of linearity, it is obvious from the graph that the basic and 0.001% bromate volumes bear a linear relation to protein content but the differentiation between the flours is decidedly better for the latter procedure.

TABLE V

REGRESSION COEFFICIENTS AND COVARIANCE ANALYSES FOR LOAF VOLUME ON PROTEIN

Individual formulas			All malt levels for different bromate treatments	
Flour treatment		Regression coefficient	Bromate treatment	Regression coefficient
Bromate	Malt			
mg.	%	b_{yz}	*mg.*	b_{yz}
0	0.0 (B_0M_0)	30.48	B_0	30.73
1	0.0 (B_1M_0)	51.60	B_1	47.32
2	0.0 (B_2M_0)	59.25	B_2	54.03
3	0.0 (B_3M_0)	43.03	B_3	41.62
0	0.5 (B_0M_1)	32.27		
1	0.5 (B_1M_1)	45.29		
2	0.5 (B_2M_1)	55.14		
3	0.5 (B_3M_1)	39.40		
0	1.0 (B_0M_2)	29.44		
1	1.0 (B_1M_2)	45.07		
2	1.0 (B_2M_2)	47.72		
3	1.0 (B_3M_2)	42.44		

COVARIANCE ANALYSES

Variance due to:	Individual formulas				All malt levels			
	D.F.	Variance	F	5% pt.	D.F.	Variance	F	5% pt.
Total	71	—	—	—	71	—	—	—
Within regressions	60	2,311.52	—	—	68	2,457.09	—	—
Between regressions	11	10,071.58	4.36	1.95	3	32,888.30	13.38	2.74

The results of these experiments show that in testing a series of flours of similar protein character where gas production is not a limiting factor, the 0.001% bromate formula in particular yields volumes which are essentially a measure of the protein content. Also, since potassium bromate influences the colloidal characteristics of the dough undergoing fermentation and different bromate levels give different volumes, it follows that when protein content and gas production are held constant, variations in loaf volume are a function of differences in colloidal characteristics.

Summary

Dried powdered gluten may be prepared which has similar strength-imparting properties to those of the original flour protein.

Seven flours ranging in protein content from 10.5% to 22.7%, obtained by enriching the lowest-protein flour with dried gluten prepared therefrom, were submitted to Brabender farinogram tests and also baked by twelve formulas comprising three levels of diastatic activity and four of potassium bromate.

The farinograms showed an increase in water-absorption and dough-development time and a decrease in "weakening area" with increasing protein content, the curves indicating transformation from a medium to strong to exceedingly strong flours.

With increasing increments of bromate the loaves exhibited a trend from under- to over-fermented characteristics.

Significant differences existed in the regression coefficients for loaf volume on protein for the various bromate levels, those for the 0.001% and 0.002% being the highest. Loaf volumes by the basic and 0.001% $KBrO_3$ formulas bore a linear relation to protein content over the entire range but the latter gave greater differentiation.

With flours of similar protein character where gas production is not a limiting factor, loaf volume is essentially a measure of protein content, and *vice versa* when a baking formula containing sufficient potassium bromate (0.001 to 0.002%) to yield approximately optimum volumes is employed.

Acknowledgments

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EXPERIMENTS ON THE SEPARATION OF SELENIUM FROM ITS COMBINATION WITH PROTEINS IN GRAIN

B. B. WESTFALL and M. I. SMITH [1]

National Institute of Health, U. S. Public Health Service, Washington, D. C.

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In the course of investigations by Smith, Westfall, and Stohlman (1938) on the fate of selenium in the animal organism, it was noted that under suitable conditions considerable amounts of selenium could be split off from protein by bromine in hydrobromic acid at room temperature without any grossly apparent dissolution of the protein. The results of earlier studies by Franke and Painter (1936), Painter and Franke (1936), Horn, Nelson, and Jones (1936), and Jones, Horn, and Gersdorff (1937), seemed to indicate that naturally occurring selenium in grain is an integral part of the protein and that it could not be removed by any procedure short of its complete disintegration by acid hydrolysis. It seemed desirable therefore to investigate the matter further in some detail.

The present experiments were carried out for the most part upon selenium-bearing wheat protein prepared from seleniferous wheat by a method similar to that described by Franke and Moxon (1934).[2] This material contained 50 ppm. selenium and was made from wheat carrying 10 ppm. selenium. Some of the experiments were also performed upon similarly prepared protein derived from oat flour, upon gluten made in this laboratory by leaching out part of the starch from selenium-bearing wheat flour, and also upon selenium-bearing whole-wheat and whole-oat flour. The technique for selenium removal consisted of bringing a weighed amount of the material in contact with the "extraction mixture" by frequent stirring, and at the end of the observation period the

[1] Assistant Chemist and Principal Pharmacologist respectively.
[2] We are indebted to A. L. Moxon of the South Dakota State College for a generous supply of this material.

selenium was determined in an aliquot of the filtered or centrifuged solution. The selenium was estimated nephelometrically as previously described (Smith, Westfall, and Stohlman, 1938; Smith, Franke, and Westfall, 1936).

Results

The data presented in Tables I to VII show the results obtained. Table I shows that 24 hours' contact of selenium-bearing protein with the oxidizing agents, bromine and hydrogen peroxide, effects a separation of the selenium. The separation is quantitative if the conditions are adequate. For the effective separation of selenium with bromine, hydrobromic acid appears to be essential though the latter alone is wholly ineffective. The presence of sufficient trichloracetic acid to prevent solution of appreciable amounts of protein does not affect the extent of selenium separation. With an extraction mixture of 1% bromine and 10% hydrobromic acid, the minimum volume in relation to the protein to effect complete separation of selenium in 24 hours at room temperature is shown in Table II, which indicates that upwards of 20 c.c. are required per gram of material.

TABLE I

THE SEPARATION OF SELENIUM FROM WHEAT PROTEIN BY OXIDIZING AGENTS

(Two g. protein, 100 c.c. aqueous extraction mixture, 24 hours' contact at room temperature)

Trichloracetic acid	Hydrobromic acid	Oxidizing agent	Selenium removed [1]
%	%		%
16	10	1% bromine	100
0	10	1% bromine	91
0	0	1% bromine	44
16	0	1% bromine	32
0	10	None	Trace
0	0	None	Trace
16	0	5% H_2O_2	32
16	0	15% H_2O_2	103

[1] In this and subsequent tables percent removed is based on total selenium found by complete oxidation by the open beaker wet ashing method (Smith, Westfall, and Stohlman, 1938; Smith, Franke, and Westfall, 1936).

TABLE II

EFFECT OF VOLUME OF EXTRACTION MIXTURE ON THE YIELD OF SELENIUM IN ITS SEPARATION FROM WHEAT PROTEIN

(One % bromine in 10% hydrobromic acid, 24 hours' contact at room temperature)

Volume	Selenium removed
c.c.	%
50	101
20	75
10	54
5	3

In Table III the minimum concentration of bromine to effect complete separation of selenium is shown, indicating that a concentration of at least 0.5% is needed. In like manner the minimum concentration of hydrobromic acid appears to be 10%, as shown in Table IV. That time and temperature of the reaction are also factors in the splitting

TABLE III

EFFECT OF CONCENTRATION OF BROMINE ON THE SEPARATION OF SELENIUM FROM WHEAT PROTEIN

(Fifty volumes of extraction mixture consisting of 16% trichloracetic acid, 10% hydrobromic acid, and bromine as indicated, 24 hours' contact at room temperature)

Concentration of bromine	Selenium removed
%	%
0.125	20
0.25	60
0.50	96
1.00	100

TABLE IV

ACCELERATING EFFECT OF HYDROBROMIC ACID ON THE RATE OF SEPARATION OF SELENIUM FROM WHEAT PROTEIN BY BROMINE

(Fifty volumes of extraction mixture consisting of 1% bromine in hydrobromic acid as indicated, 24 hours' contact at room temperature)

Concentration of hydrobromic acid	Selenium removed
%	%
0.0	44
2.5	62
5.0	76
10.0	98

TABLE V

EFFECT OF TIME AND TEMPERATURE ON THE RATE OF SEPARATION OF SELENIUM FROM WHEAT PROTEIN BY BROMINE IN HYDROBROMIC ACID

(Fifty volumes of extraction mixture consisting of 1% bromine and 10% hydrobromic acid)

Time	Temperature, Centigrade	Selenium removed
Hrs.		%
1½	25	22
3	25	44
6	25	62
24	20–25	100
6	0	5
3	40	80
6	40	87

TABLE VI

EFFECT OF CONCENTRATION OF H_2O_2 ON THE RATE OF SEPARATION OF SELENIUM FROM WHEAT PROTEIN

(Fifty volumes of extraction mixture, 24 hours' contact at room temperature)

Hydrogen peroxide	Trichloracetic acid	Selenium removed
%	%	%
6	16	32
6	0	31
12	0	40
12	0	46
18	16	100
18	0	92

TABLE VII

SEPARATION OF SELENIUM FROM ITS COMBINATION IN GRAIN AND IN GRAIN PROTEIN

(One % bromine in 10% hydrobromic acid, 24 hours' contact at room temperature, 50 c.c. per g. material)

No.	Sample	Selenium content	Selenium removed
		Mg. %	%
1	Oats	0.7	65
2	Oats	0.9	80
3	Oats	1.4	36
4	Oats	1.0	25
5	Wheat	1.0	36
6	Wheat	1.1	60
7	Wheat	1.9	70
8	Oat protein	1.2	100
9	Wheat gluten	3.8	95
10	Wheat protein, lot 1	5.0	95
11	Wheat protein, lot 2	5.1	106
12	Wheat protein, lot 3	5.0	93
13	Wheat protein, lot 4	4.7	100

off of selenium from seleniferous protein is clearly shown in Table V.

In Table VI the concentration of hydrogen peroxide most effective in removing selenium is shown, and this appears to be 18% if used in the proportion of 50 c.c. per gram of material.

In order to ascertain the applicability of the above procedures to the selenium in whole grain, several samples of ground selenium-bearing oats and wheat were treated with bromine in hydrobromic acid or with hydrogen peroxide under the optimum conditions and the percentage of selenium so removed determined. The results as shown in Table VII indicate that selenium can be separated from whole grain as well as from grain protein, though removal in the former case is often incom-

plete.[3] Samples 3, 4, 5, and 6, which gave low values, were subsequently treated in the same manner with the bromine increased to a concentration of 3% with better results, the percentages of selenium obtained having been increased to 62, 88, 50, and 81 respectively. In another experiment samples 4 and 5 were treated with 18% hydrogen peroxide, and the percentages of selenium recovered were 100 and 90, respectively. It seems probable that some of the low recoveries of selenium from whole grain when treated with bromine in hydrobromic acid may be due in part to interference of starch with the recovery of the volatile bromide of selenium in the process of distillation.

Discussion

It is not implied that these results are suggested as a means of detoxifying selenium-bearing grain. Indeed wheat gluten treated with bromine as described here becomes highly toxic and apparently out of all proportion to the bromine it retains. Wheat gluten treated with hydrogen peroxide in a manner similar to that used for the removal of selenium is apparently devoid of toxicity as judged by feeding experiments in rats, but it is probable that such treatment may affect its nutritional value. We report these experiments merely to show that selenium can be split off from grain and grain protein under suitable conditions without disintegrating the protein.

It is reasonable to inquire what light, if any, the present experiments throw on the chemical nature of the selenium in grain protein. Blumenthal and Clarke (1935) have succeeded in splitting off a fraction of the protein sulfur as inorganic sulfate with bromine, which they consider as neither cystine nor methionine; and Smith and Harris (1936) showed that cystine sulfur in sheep's wool is attacked even by 3% hydrogen peroxide. In our experiments at least a portion of the selenium separated from protein with bromine in hydrobromic acid can be precipitated as elementary selenium by reduction with sulfur dioxide and hydroxylamine hydrochloride.

Similarly the selenium split off with hydrogen peroxide can also be precipitated in its elementary form by reduction after a preliminary brief treatment with bromine in hydrobromic acid. The selenium thus appears to behave like the inorganic selenite or selenate. This, however, does not exclude the possibility of its being an organic compound of selenium, either as it naturally occurs in protein or as some derivative, for we have observed that the very labile selenium of the organic compound diseleno diacetic acid[4] can also be removed quantitatively by

[3] Curl and Osborn (J. Assoc. Official Agr. Chem. 21: 228–235, 1938) have reported the extraction of 81% of the selenium from a mixed sample of sunflower seed, wheat, barley, and oats by refluxing 1½ hours with 15% bromine in 48% hydrobromic acid. Their mixed sample contained 16.5 mg. percent selenium.

[4] Diseleno diacetic acid, $HOOC \cdot CH_2 \cdot Se \cdot Se \cdot CH_2 \cdot COOH$, was kindly supplied by H. P. Ward of the Catholic University of America.

reduction with sulfur dioxide and hydroxylamine hydrochloride after a brief preliminary treatment with bromine in hydrobromic acid. Taking everything into consideration it appears likely that the major portion of the selenium split off from the protein by the two procedures described is probably inorganic and gives no clue to the chemical nature of its precursor in the protein other than that it is moderately labile.

A series of analyses was made to determine the nitrogen and sulfur content of the selenium-containing extracts obtained by deselenizing two samples of seleniferous wheat protein.[5] For comparison analyses were also made for the nitrogen and sulfur content of similar extracts obtained from a sample of non-seleniferous wheat gluten. The results, which are summarized in Table VIII, show that all the extracts con-

TABLE VIII

NITROGEN AND SULFUR CONTENT OF PROTEIN EXTRACTS OBTAINED IN THE PROCESS OF DESELENIZATION

Description of preparation	N[1]	S[1]	Percent of total	
			N	S
	%	%	%	%
1. *Extracts of selenium-bearing wheat gluten containing 4.26% N and 0.24% S*				
Trichloracetic acid extract	0.35	0.03	8.2	12.5
Trichloracetic-bromine-hydrobromic acid extract	0.91	0.09	21.4	37.0
Trichloracetic acid-hydrogen peroxide extract	1.12	0.16	26.3	67.0
2. *Extracts of selenium-bearing wheat protein containing 13.70% N and 0.93% S*				
Trichloracetic acid extract	1.12	0.06	8.2	6.5
Trichloracetic-bromine-hydrobromic acid extract	1.97	0.23	14.4	24.7
Trichloracetic acid—hydrogen peroxide extract	3.12	0.24	22.8	25.9
Bromine-hydrobromic acid extract	2.08	0.30	15.2	32.0
Hydrobromic acid extract	3.46	0.11	25.0	11.8
3. *Extracts of non-seleniferous wheat gluten containing 14.40% N and 0.74% S*				
Trichloracetic acid extract	1.05	0.04	7.1	5.4
Trichloracetic-bromine-hydrobromic acid extract	2.27	0.14	15.8	19.0
Trichloracetic acid-hydrogen peroxide extract	3.24	0.17	23.2	23.0

[1] Nitrogen by the Kjeldahl method; sulfur in extracts by the Benedict-Denis, in proteins by the Parr bomb method.

tained some nitrogen and sulfur. Since the selenium-free trichloracetic acid extracts contained as much as 8% of the total nitrogen and 12% of the total sulfur, not more than about 6% of the total nitrogen nor more than 18% of the total sulfur could be intimately associated with the selenium of the protein. Even this becomes doubtful in view of the fact that a hydrobromic acid extract of a seleniferous protein con-

[5] For the nitrogen determinations thanks are due to E. Elvove and C. G. Remsburg of this Institute. At E. Elvove's suggestion the excess bromine was reduced with zinc dust prior to digestion since bromine may cause loss of nitrogen.

taining not more than a trace of its selenium contained actually more nitrogen than the corresponding bromine-hydrobromic acid extract which had removed all the protein selenium. However this increase probably represents simply some acid-soluble fraction, since some protein is precipitated from the hydrobromic acid extract on subsequent addition of bromine. Since a portion of the nitrogen and sulfur is removed by both oxidizing agents and especially since the sulfur in these is higher than in the hydrobromic acid extract it would seem not improbable that the breaking of some sulfur linkages may accompany the selenium extractions. Nevertheless extracts of non-seleniferous wheat gluten contained approximately as much of its total nitrogen and sulfur as did the extracts of the selenium-bearing proteins.

Summary

The selenium which naturally occurs in grain protein can be removed quantitatively under suitable conditions with (1) bromine in hydrobromic acid, or (2) hydrogen peroxide. While this entails no grossly apparent hydrolysis of the protein nor its disintegration, there is some possibility that it is accompanied by the removal of a certain fraction of nitrogen and sulfur.

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EVALUATION OF YEAST ACTIVITY BY MEANS OF THE SANDSTEDT-BLISH PRESSURE METER [1]

R. T. BOHN and H. H. FAVOR

The Great Atlantic and Pacific Tea Co., New York, N. Y.

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The testing of yeast used in commercial bread production for uniformity of strength, as well as the testing of various brands of yeast for comparative gas production activities, is one of the routine functions of the bakery service laboratory. While other qualities of yeast, such as proteolytic activity and rope spore count, are of importance in determining the commercial value of yeast, the rate of gas production and the total amount of gas produced over a period of time comparable to normal fermentation are of major importance and should be known independently of other characteristics.

The strength of yeast used in bread making is primarily dependent on the rate with which it produces carbon dioxide when an adequate supply of fermentable carbohydrate is available. Cook and Malloch (1930) outlined a method for determining the carbon dioxide produced from maltose by a definite quantity of yeast acting in a liquid medium. This required adjustment of pH to that of a normal fermenting dough and constant agitation of the fermenting medium by mechanical shaking. This method was, however, open to the objection cited by the authors that the relative efficiencies in dough of two strains of yeast are not necessarily the same as in liquid media.

The shortcomings of a method which does not test yeast in the medium in which it is used, are recognized by the yeast manufacturers themselves, who control the uniformity of their product by making a dough of flour, water, fermentable carbohydrate (sugar) and shortening of the consistency of normal bread dough and recording the time required for it to reach a definite height. Note that this is what is known as a straight dough. Other methods along the lines of testing yeast *in situ* depend on measuring the amount of gas evolved from a fermenting dough, including that required for raising the dough. Many such methods have been proposed in the literature. Bailey and Johnson (1924) measured the gas produced on fermentation by collecting the gas in an inverted burette. C. W. Brabender (1934) developed an apparatus known as the fermentograph which is so arranged that the amount of carbon dioxide given off by the fermenting dough displaces an equal volume of water, the weight of which is recorded automatically by a recording mechanism.

[1] Sub-committee report, 1937–38 Committee on Methods of Analysis.

Obviously this method of measuring the gas-producing activity of a dough can be utilized for determining the rates of activity of various types and brands of yeast. Near and Sullivan (1935) published their observations of the variability in gassing strength of several brands of yeast, as measured by this apparatus. It was their opinion that corresponding periods of rate of gas production could be correlated very well with the gas produced during the proofing period of the baking test.

The manometric method for determining gas-producing capacity of flour designed by Blish, Sandstedt, and Astleford (1932) and refined by Sandstedt and Blish (1934) is widely used for commercial control of "gassing" power of flour without, however, sufficient emphasis on the different activities of various types of yeast. The work we have done shows clearly that there is sufficient difference in activity between different types of yeasts to make it important to specify the source of the yeast used in any series of collaborative tests on gassing strength of flour.

A comparative study of the Bailey-Johnson, fermentograph, and Sandstedt-Blish manometric methods for determining gassing power of flour was made by Eva, Geddes, and Frisell (1937). They reached the conclusion that there was little to choose between the three methods from the standpoint of utility, and that the adoption of any particular method could be based on other considerations.

The general acceptance of the Sandstedt-Blish pressure meter as finally manufactured as a convenient apparatus for measuring gas-producing activity of flours led to an investigation of its utility for testing the uniformity and relative activity of yeast. This was one of the projects of the Methods Committee for 1937.

Experimental Work

In the following experiments yeasts are referred to as A, B, C, etc. No comparison can be made between the strengths of the yeasts as given in the various tables, as the same letters do not always identify the same yeast.

The first tests were designed to determine if a normally diastated flour could be used without any source of additional fermentable carbohydrates. The method was the same as used in determining the gassing power of a flour. Ten g. of flour was mixed with 0.3 g. of yeast (3% based on flour) and 7 c.c. water and the dough allowed to ferment at 30° C. in a thermostatically controlled water bath. Readings were made of both the upper and lower levels of the mercury column and the difference recorded as millimeters of pressure. We found that the accuracy of this determination was increased by releasing the

TABLE I

GAS EVOLVED FROM DIASTATED FLOUR

Time	Rate per hour		Total gas	
	Yeast A	Yeast B	Yeast A	Yeast B
hrs.	*mm.*	*mm.*	*mm.*	*mm.*
1	88.2	84.0	88.2	84.0
2	151.5	133.9	239.7	217.9
3	135.5	137.0	375.2	354.9
4	47.3	59.5	422.5	414.4
5	28.3	30.2	450.8	444.6
6	19.9	20.4	470.7	465.0

pressure at the end of each hour. The gas must be allowed to escape slowly so that the cooling effect due to adiabatic expansion does not affect the reading.

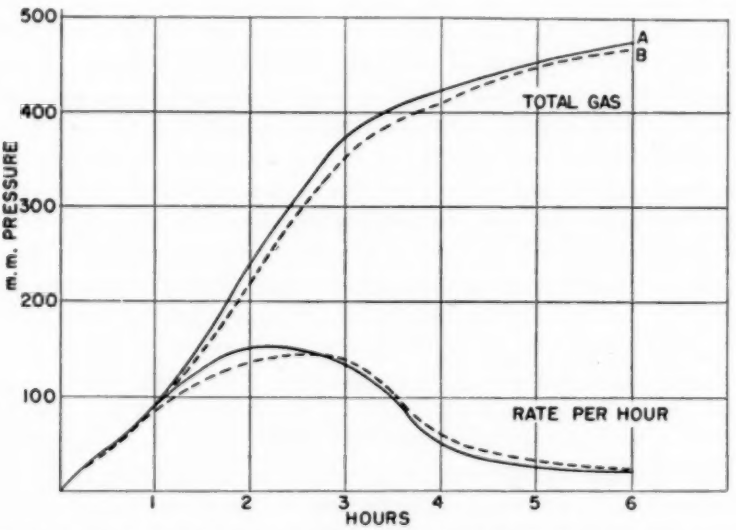

Fig. 1. Gas production with yeasts A and B and a diastated flour (3% yeast and no sugar).

As indicated by the results in Table I, and shown in Figure 1, while yeasts may vary in activity during the first hour or two of fermentation when there is an oversupply of carbohydrate, at later periods the rate of production of fermentable carbohydrates by diastatic activity is the limiting factor in gas production. Thus a yeast which ferments maltose slowly may produce as much total gas or even more at the end of the fermentation period as the one more active the first few hours. This observation is of practical interest, as the conditions of the method approximate those existing in a bread sponge.

This illustrates the importance of specifying the kind of yeast used in the determination of gassing power. Thus there is considerable difference in the gas produced per hour by the two yeasts until the fifth hour. Two laboratories using the same flour would not agree on this figure unless the fifth or sixth hour were taken as the measure of diastatic activity.

In testing yeast for use in sponge fermentation it would seem advisable to test it without addition of sucrose. However, even with a flour of good diastatic capacity the activity of the yeast will be limited in the later stages to the maltose produced by diastatic action and the ability to ferment maltose, and misleading conclusions regarding the strength of the yeast may be reached if the results are not properly interpreted.

In the dough stage of the sponge process, excess sucrose is present and it is important therefore to know how the yeast will behave under such conditions. Also if yeast is to be used in straight doughs it would seem advisable to test it in the presence of sucrose. We have, therefore, experimented with adding sucrose in varying amounts, using the same method described above with the results shown in Table II and in Figure 2. The percentage of sugar was based on the flour.

TABLE II

EFFECT OF ADDING SUCROSE TO DIASTATED FLOUR

Time	Sugar			
	0	2.5%	5.0%	7.5%
hrs.	*mm.*	*mm.*	*mm.*	*mm.*
1	85	114	109	102
2	137	127	138	139
3	140	113	117	127
4	55	98	97	114
5	34	81	86	101
6	25	60	85	96
Total	476	593	632	679

Table II shows that the production of gas from the dough fermenting in the pressure meter drops off rapidly after three hours when no sucrose is present. This is also shown in Table I and Figure 1. Therefore, if any information is desired regarding the activity of the yeast in the presence of excess carbohydrate after that time, fermenting material from an additional source must be added. After many experiments we selected 0.3 g. or 3%, based on the flour, of sugar, as giving us all the data normally required on the relative activity of yeast in the presence of sucrose. It is interesting to note that the

rate of gas production is faster during the third hour when no sugar is present than at any other time.

We also investigated the advisability of using maltose in place of sucrose, as this sugar is the one normally present in a fermenting

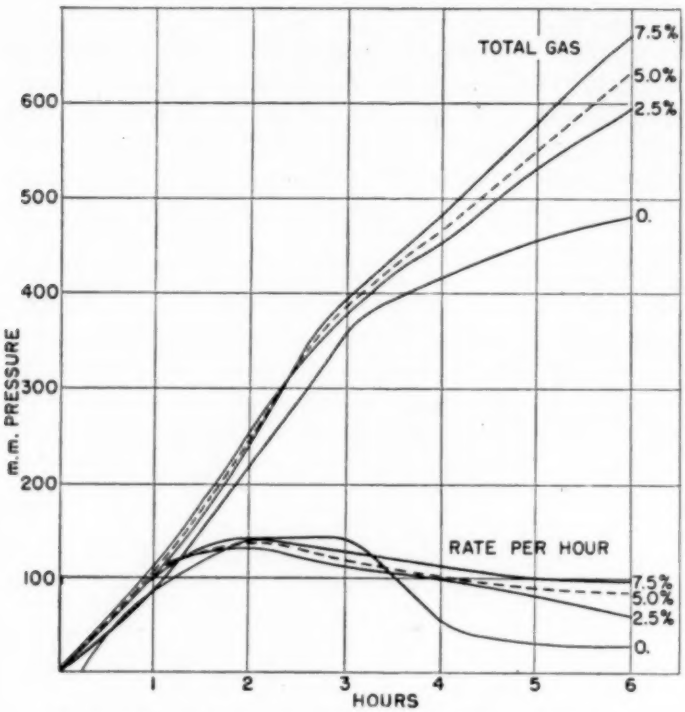

Fig. 2. Effect of added sucrose (10 g. of diastated flour and 3% yeast).

sponge as a result of diastatic action of the flour or malt supplement added by the baker. We show in Table III a comparison of the two yeasts tested by the pressure-meter method in the absence of added sucrose, with 3% sucrose, and with 3% maltose.[2]

Yeast B was slower than A in producing gas the first two hours from both the no-sugar and the maltose dough. It produced less gas from maltose sugar at the end of 4 hours, which in our work covers the sponge fermentation time, but produced as much gas in 4 hours as A in the dough without added sugar. A review of the sucrose fermentation is interesting, because it indicates that during the first hour of fermentation the two yeasts are the same but that yeast B is slower the second hour. From baking tests we have made, the rate of gas

[2] Difco Standardized, Difco Laboratory, Detroit.

production from the sucrose dough appears to influence the pan proofing time of the sponge-dough process.

TABLE III

COMPARISON OF YEASTS USING DIFFERENT SUGARS

Time	No sugar		0.3 g. sucrose		0.3 g. maltose	
	A	B	A	B	A	B
hrs.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
1	94	81	118	118	88	80
2	136	125	129	113	126	114
3	120	124	129	121	144	135
4	47	69	96	91	131	125
5	24	31	85	85	83	95
6	23	24	63	71	50	70
Total	444	454	620	599	622	619
Total—4 hrs.	397	399	472	443	489	454

As the addition of maltose did not reveal any differences between the activities of yeasts in our tests other than shown by the no-sugar dough we continued our investigations with the no-sugar and sucrose doughs. We also studied the effect of absorption, varying it from 50% to 100% based on the flour, with results shown in Table IV.

TABLE IV

EFFECT OF ABSORPTION ON GAS PRODUCTION—0.3 GRAM SUCROSE

Time	Absorption		
	50%	70%	100%
hrs.	*mm.*	*mm.*	*mm.*
1	88	90	85
2	129	140	148
3	108	131	143
4	35	41	45
5	33	32	35
6	14	17	20

The softer doughs generate more gas per hour than the stiffer ones but there appeared to be no physical advantage over the dough made with 7 c.c. or 70% water. This amount we found convenient. On the other hand the stiffer (50%) dough was harder to mix. We therefore continued with 7 c.c. of water and recommend it as a convenient amount to use. Further, this is the absorption suggested by Sandstedt and Blish for the determination of gassing power of flour and is the absorption normally encountered in sponge and dough fermentation.

The pressure-meter method can be used very satisfactorily for

determining the uniformity of any one type of yeast. It may be used with or without sugar for that purpose. Once the characteristics of any one type of yeast have been determined in terms of pressure-meter readings per hour, a standard can be set up which shipments can be expected to match with a reasonable degree of accuracy. We

TABLE V

PRESSURE-METER READINGS ON ONE BRAND OF YEAST IN PRESENCE OF SUCROSE

Weeks	Hours					
	1	2	3	4	5	6
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
1	121	128	97	93	92	73
2	110	133	116	89	89	63
3	117	132	115	96	89	74
4	120	114	116	97	85	70
5	102	133	117	99	80	65
6	121	142	108	100	80	68
7	115	131	111	101	81	70
8	117	130	121	96	78	64
9	120	132	114	103	79	63
10	118	132	112	94	80	72
Average	116	131	113	97	83	68

show in Table V the results obtained on one brand of yeast in the presence of sucrose over a period of ten weeks. The figures shown are the average of triplicate determinations.

TABLE VI

PRESSURE-METER READINGS—NO SUGAR

Weeks	Hours					
	1	2	3	4	5	6
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
1	75	123	137	61	34	20
2	78	126	132	60	33	19
3	87	143	135	57	28	20
4	86	146	139	59	28	19
5	83	135	139	63	27	19
6	89	131	134	57	30	23
7	90	131	137	60	31	23
Average	84	134	137	60	30	20

Table VI shows results of another yeast in absence of sucrose. This yeast was the same as yeast B in Table I. The data illustrate the uniformity with which yeast is delivered to the baker. They also show clearly that the diastatic activity of a flour is the limiting factor

in gas production when no added sugar is present, and verify the observations of Sandstedt and Blish (1934) that yeast variability with any one type of yeast is insignificant in determining gassing power when yeast is fresh.

Tests made to determine whether the method could be used to evaluate various brands of yeast gave interesting results. Thus data on five different yeasts in the presence of sugar are given in Table VII.

TABLE VII

COMPARISON OF YEASTS—3 GRAMS SUGAR

Yeast	Hours						
	1	2	3	4	5	6	Total
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
A	121	149	113	99	88	73	643
B	110	140	106	91	75	67	589
C	81	131	101	93	88	85	579
D	102	125	87	79	74	64	531
E	118	135	128	116	95	62	662

These data present some interesting differences, clearly showing why it is necessary to run the test over at least 5 hours in order to get information on the activity of a yeast and its value from the standpoint of gassing power. Thus yeast A is very active throughout the entire period of the test. Yeast C shows a slow start but a well-sustained activity during the later period of the test. Yeast D starts out well but shows a very decided decrease in activity between the second and third hour. Thus if the test had been run only two hours or if the yeast had been tested in a medium consisting of low percentage of yeast and with salt present, different results would have been obtained.

TABLE VIII

COMPARISON OF YEASTS IN GAS PRODUCTION PER HOUR

Time	Sugar			No sugar		
	A	B	C	A	B	C
hrs.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
1	126	118	127	97	120	85
2	127	135	127	136	139	128
3	115	128	121	119	116	132
4	102	116	104	45	43	65
5	87	94	89	28	28	35
6	58	59	71	21	22	25
Total	615	650	639	446	468	470

In another series of tests several brands of yeast were run with and without sugar with the results shown in Table VIII.

It is evident that yeast B is slightly slower in activity the first hour in the presence of sugar but thereafter is very fast. In the absence of sugar it is by far the most active of the three yeasts in the first hour.

The data indicate that the method suggested can be used to determine the uniformity of any one type of yeast and to make comparisons between different brands. However, anyone using the pressure-meter method, either with or without sugar, to evaluate yeasts will have to familiarize himself with the correlation to be expected between the results of the test and actual commercial bake shop practice.

Thus one hour of fermentation of the dough in the pressure meter at 30° C. corresponds to about the first hour of commercial sponge fermentation, depending on temperature at which the sponge was set and whether or not some salt was used. The percentage of yeast (3.0%), however, is not far different from that present in the commercial sponge if we consider 1.75% yeast, based on total flour, as an average amount used by the baker.

For obtaining information regarding the behavior of yeast in sponge fermentation a six-hour testing period is not necessary. From our experience all necessary information is obtained from the four-hour period. This time without sugar shows quite definitely differences in yeast activity that are valuable in making comparisons of different types of yeast for sponge fermentation.

TABLE IX

GAS PRODUCTION FOR FOUR YEASTS WITH NO SUGAR AND WITH 0.3 GRAM SUGAR

Time	No sugar				Sugar			
	A	B	C	D	A	B	C	D
hrs.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
1	99	75	85	82	111	117	109	128
2	151	132	137	138	142	134	119	125
3	134	139	140	147	137	122	117	123
4	48	62	42	54	111	110	106	112
5	28	33	34	38	91	92	79	81

We made experiments to determine what effect the rate of gas production has on the time of pan proof of a straight dough, using the A.A.C.C. baking test and with modifications to duplicate commercial straight doughs. The yeasts used gave the pressure-meter readings, with and without sugar, shown in Table IX.

When the A.A.C.C. test doughs were made, 15 grams of the dough

were placed in the pressure meter and readings taken every hour. The data thus obtained are given in Table X and graphically in Figures 3 and 4, in which is shown the gassing rate at the time the dough was put in the oven.

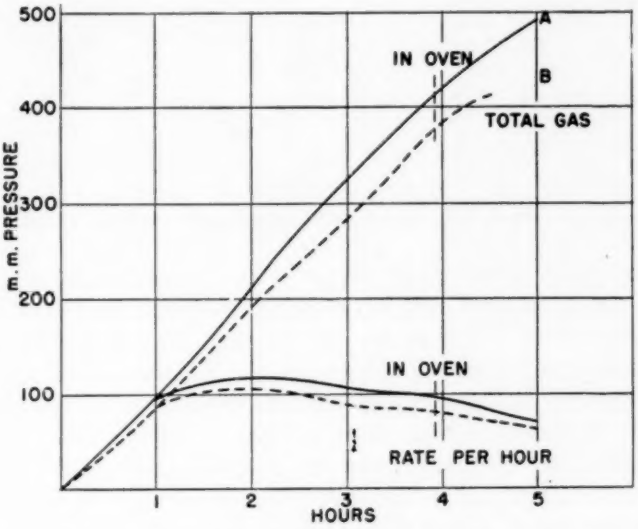

Fig. 3. Gas production with yeasts A and B, with A.A.C.C. baking-test doughs.

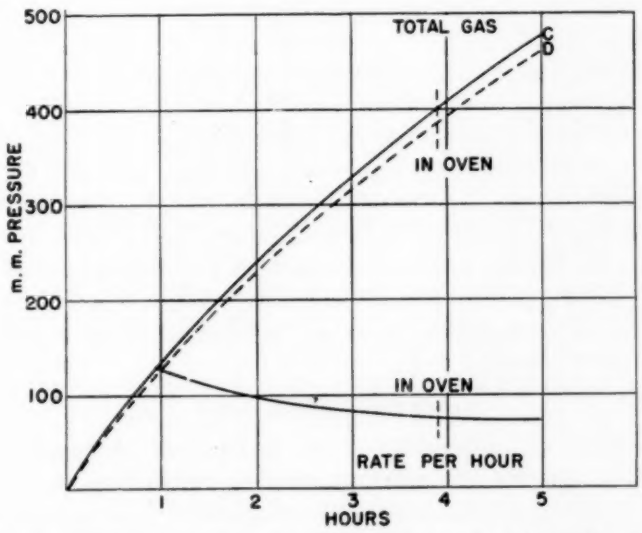

Fig. 4. Gas production with yeasts C and D, with A.A.C.C. baking-test doughs.

TABLE X

GAS PRODUCED FROM 15 GRAMS A.A.C.C. TEST DOUGH [1]

Time	Yeasts			
	A	B	C	D
hrs.	*mm.*	*mm.*	*mm.*	*mm.*
1	96	87	133	125
2	117	106	105	106
3	109	88	94	91
4	97	79	73	72
5	72	65	72	77
Proofing time (*min.*)	55	72	55	55

[1] Time of running and the flours were not the same for yeasts A and B as for C and D.

There was a difference in the activity of the doughs as they fermented, which was reflected in the height to which they rose; but only the proofing time, which is the most critical stage from the practical standpoint, was recorded. This is given in Table X. The data in this table show that the differences between the yeasts found by the pressure-meter readings are of significance. Thus yeast B is slower than yeast A in the pressure-meter reading with sugar and is also slower in liberating gas in the A.A.C.C. test and slower in pan proof. On the other hand, yeasts C and D are similar in both the pressure-meter and in the test dough, including proofing time. This verifies the thought expressed by many that any standardization of the A.A.C.C. baking test must take into consideration the activity of different types of yeast.

These results show that for straight doughs baked by the A.A.C.C. procedure the pressure-meter readings obtained in the manner suggested give a very definite valuation of the gas-production capacity of a yeast. Additional tests made with commercial straight doughs showed similar results, although in these tests the slower activity of the yeast due to higher concentration of salt and smaller amounts of yeast did not reveal as large differences in proofing time and in some cases completely eliminated the slight difference in proofing time which was noted between yeasts with the same flour when baked by the A.A.C.C. procedure.

Sponge Baking Tests

Our results with laboratory sponge baking tests designed to imitate commercial practice showed that the gas production in the sponge stage proceeded at the same rate as found by the pressure-meter readings. This is to be expected from the similar composition of the commercial sponge and the dough used in the pressure meter. We

did not attempt to correlate pressure-meter readings with volume of the sponge as this was affected by too many variables to be of much value.

In our experiments we prepared a sponge of following composition:

Flour	60.0 grams
Water	36.0 grams
Yeast	2.0 grams
Yeast food	0.25 gram
Salt	0.25 gram

In one series of experiments the temperature of the water bath was started at 76° F. and the temperature raised two degrees per hour until at the end of 5 hours the temperature was 86° F. This is approximately the rate at which commercial sponges increase in temperature. The pressure measured at any hour also measures the volume increase due to effect of increase in temperature, but this obviously is constant and was disregarded.

The dough was made by adding 7 g. of flour, 0.5 g. sugar, and 0.3 g. salt. The results are shown graphically in Figure 5. Data are given

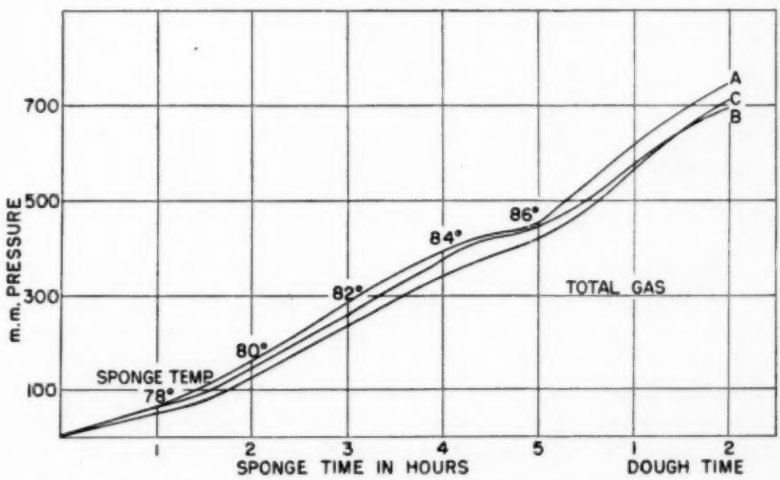

Fig. 5. Gas production in sponge doughs with progressively increasing temperatures.

in Table XI. It is evident that the three yeasts show the same activity in the sponge as in the pressure-meter method, the results of which are shown in Table XII.

Yeast A is most active and produced the most total gas by both the regular pressure-meter method and under the conditions set up in the tests. Yeasts A and B had apparently exhausted the natural sucrose of the flour and the maltose formed during the cooler stages of fer-

mentation before yeast C, which was producing more gas per hour at the end of the fifth hour, and no doubt if allowed to continue would have produced as much total gas as A and B. The yeasts exhibited the same behavior in the dough stage. Yeast A is most active. In the tests made yeast C was more active than B at this stage.

TABLE XI

GAS PRODUCTION FROM SPONGE-DOUGH PROCESS

Readings in Millimeters

Temp. sponge	Time (*hrs.*)	Total gas			Rate per hour		
		A	B	C	A	B	C
		Sponge					
76	1	68	54	45	68	54	45
80	2	164	141	124	96	87	79
82	3	289	259	228	125	118	104
84	4	398	382	339	109	123	111
86	5	447	434	417	49	52	78
		Dough					
86	1	168	140	148	168	140	148
86	2	298	261	284	130	121	136

TABLE XII

COMPARISON OF YEASTS

Pressure-Meter Readings with 0.3 g. Sugar

Yeasts	Hours						Total
	1	2	3	4	5	6	
A	129	132	108	104	89	88	650
B	120	137	116	90	79	68	610
C	110	131	107	95	87	83	613

We found that the pressure-meter evaluation of the activity of the yeasts in presence of sugar was related to the time required to proof the dough to a definite height. Final loaf volumes, however, are the result of the many factors which influence the maturing and gas-retention properties of a dough and hence did not always correlate with pan-proofing time. This is the reason we have found it desirable to segregate gas-production activity of a yeast from other properties as much as possible.

We also did some work with the dough-expansion test, which is used by yeast companies in controlling the uniformity of their product. However, we have not enough data to say definitely that the pressure-meter method suggested will give more valuable information. We do

wish to point out that the dough-expansion method is obviously designed for testing yeasts used in straight doughs and it does not give the information desired for yeasts used in sponge doughs by which, as claimed by most authorities, 90% of the bread baked in this country is made. The dough-expansion method does not take into consideration the different behavior of various types of flour. Any method which separates gassing strength of yeast from other properties and uses flour only as a substrate in which to test the yeast, is desirable.

Various types of flour differ so much in their reaction to proteolytic enzymes and acidity that it is not possible to judge the relative gassing power of yeast from the loaf volume of bread made by any one formula using various brands of yeasts.

We believe the suggested pressure-meter method with and without added sugar gives much valuable information regarding the ability of yeast to produce carbon dioxide from a dough, but that it must be supplemented by baking tests in order to determine the effect of other properties of the yeast on the maturing of the dough and character of the bread. Our experience has been that the pressure-meter readings are a very valuable guide in helping evaluate yeast.

Summary

The Sandstedt-Blish pressure meter is an excellent piece of equipment for conveniently determining the gas-producing strength of yeast in doughs with or without added sugar. It can be used to determine the uniformity of any one type of yeast or to make comparisons between various types. The results obtained are a valuable aid in evaluating yeasts but should be supplemented by baking tests to determine the effect of other characteristics of the yeast on maturing of the dough and on bread quality.

Additional evidence is shown in support of Sandstedt and Blish (1934) that yeast variability is usually of very little significance in determining the gassing power of a flour, provided of course that fresh yeast is used.

Data are shown which indicate the necessity of knowing the source and type of yeast when making studies of rate of gas production of a flour. Yeasts cannot be used interchangeably for this purpose unless previous testings on a known or standard flour have shown them to be similar.

The effect of type and activity of yeast is an important variable in the A.A.C.C. baking test and any standardization of that test must include certain specifications designed to control the characteristics of the yeast.

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A RAPID METHOD FOR THE DETERMINATION OF WHEAT AND FLOUR PIGMENTS [1]

D. S. BINNINGTON [2] and W. F. GEDDES [3]

(Read at the Annual Meeting, May 1938)

Several colorimetric methods have been described for estimating the pigment content of cereal products which are based essentially upon the "gasoline color value" test devised by Winton (1911). In general, such methods require an extended time of extraction, usually over night, and are thus not suited to problems involved in mill control. Coleman and Christie (1926) utilized high-speed stirring to accelerate the extraction, and in this manner succeeded in reducing the time required to 30 minutes. Their method, however, necessitates the use of a separate stirring motor of the malted-milk-mixer type for each test and is therefore, from the standpoint of cost, not well adapted to carrying out a number of tests simultaneously.

In addition to the lengthy extraction time required by the older methods, difficulty was frequently encountered in matching the extracts so obtained against the potassium chromate standards. This objection was overcome by Geddes, Binnington, and Whiteside (1934), who em-

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Sub-committee report 1937–38 Committee on Methods of Analysis.
The authors wish to acknowledge the assistance of H. Johannson and L. D. Sibbitt in securing many of the data presented.
[2] Research Assistant, Associate Committee on Grain Research.
[3] Chief Chemist, Grain Research Laboratory, Board of Grain Commissioners for Canada.

ployed unfiltered mercury-arc radiation as an illuminant and developed a colorimetric method in which the carotene equivalents corresponding to selected concentrations of potassium chromate were employed directly. This method is described in "Cereal Laboratory Methods" as an alternative to the spectrophotometric procedure for the determination of carotenoid pigments. While more accurate, this method is no more rapid than the conventional gasoline color value test.

In these prior studies, the investigators employed some form of petroleum hydrocarbon as a solvent, either alone or in admixture with absolute ethyl alcohol. Binnington, Sibbitt, and Geddes (1938) pointed out the deficiencies of such solvents and carried out an extensive survey of a number of commercially available organic compounds which resulted in the selection of water-saturated n-butyl alcohol as most nearly approaching the ideal. Experience gained with this solvent over a period of a year has confirmed its desirability and indicated the possibility of developing a rapid, simple, and accurate method involving the minimum of expenditure for special equipment. Such a method, if available, would appear to be of considerable practical value particularly in mill control. In the present paper a method which meets the requirements of rapidity and accuracy, together with simplicity and low equipment cost, is described.

Experimental

In developing a rapid colorimetric method using water-saturated n-butyl alcohol as a solvent, it is necessary to determine the conditions under which maximum extraction can be secured in minimum time, develop a method of clarification which would preferably not involve the use of a centrifuge, and recompute the carotene equivalents of the potassium chromate standards for this solvent. For measuring the carotene content of the extracts the A. A. C. C. spectrophotometric method employing a Bausch and Lomb instrument equipped with a scale reading directly in percentage transmittancy was used; a sample-to-solvent ratio of 20 g. to 100 c.c. was used in all cases. The transmittancy readings obtained in a 10 cm. cell were converted into the carotene equivalents by means of a table based upon the specific transmissive index (K) for carotene of 1.6632 in n-butyl alcohol—the value found by Binnington, Sibbitt, and Geddes (1938).

Time of extraction.—The results of a preliminary study with flour indicated that maximum extraction was obtained in 45 minutes without continued shaking; accordingly, experiments were undertaken to determine the shortest time required. For this purpose two experimentally milled unbleached and two commercially milled bleached flours were selected. The procedure followed consisted simply of adding the solvent

to the flour, shaking by hand to ensure thorough mixing, standing for the prescribed length of time, and shaking immediately before centrifuging. The results of duplicate tests are presented in Table I and show that extraction is complete in all cases at the expiration of 15 minutes. Within the range studied (0.92 to 3.05 p.p.m.) the actual pigment content would appear to be without influence upon the results.

TABLE I

EFFECT OF EXTRACTION TIME UPON THE QUANTITY OF PIGMENT REMOVED FROM HARD RED SPRING WHEAT FLOURS

Time of extraction	Carotene p.p.m. (spectrophotometer)							
	Exp. milled unbleached flour [1]		Exp. milled unbleached flour [2]		Com. milled bleached (med. grade)		Com. milled bleached (high grade)	
Min.	a_1	b_1	*a*	*b*	*a*	*b*	*a*	*b*
5	2.97	2.96	1.91	1.92	1.81	1.83	0.92	0.92
15	3.05	3.04	2.06	2.05	1.90	1.87	0.93	0.93
30	3.06	3.05	2.06	2.06	1.87	1.87	0.93	0.93
60	3.05	3.06	2.07	2.06	1.88	1.88	0.93	0.93
16–18 hrs. (over night)	3.05	3.05	2.09	2.08	1.85	1.87	0.93	0.92

[1] Letters *a* and *b* represent duplicate tests.

TABLE II

EFFECT OF EXTRACTION TIME AND TYPE OF GRIND UPON THE QUANTITY OF PIGMENT EXTRACTED FROM HARD RED SPRING AND DURUM WHEATS

Sample	Grind	Carotene p.p.m. (spectrophotometer)					Remarks
		Time of extraction					
		½ hr.	1 hr.	2 hrs.	4 hrs.	16–18 hrs. (over night)	
1 Hard	Wiley, ½ mm. screen	3.45	3.64	3.65	3.65	—	Standing [1]
		3.51	3.63	3.63	3.67	—	Shaken [2]
1 Hard	Allis-Chalmers mill	3.45	3.65	3.66	3.64	—	Standing [1]
		3.45	3.61	3.63	3.66	—	Shaken [2]
2 C. W. Durum	Hobart [3]	4.22	5.30	5.34	5.54	5.86	Duplicate tests
		4.22	5.30	5.32	5.56	5.84	
1 C.W. Garnet	Hobart [3]	4.62	5.30	5.50	5.54	5.72	Duplicate tests
		4.64	5.30	5.48	5.58	5.72	
1 Nor.	Hobart [3]	3.34	3.98	4.04	4.00	3.98	Duplicate tests
		3.34	4.02	4.04	4.00	4.00	

[1] Shaken by hand at commencement and end of test.
[2] Shaken mechanically throughout entire extraction period.
[3] Finest possible grind employing Hobart Model 6 burr mill (equipped with stationary burr No. 4317, No. 2 R.N. Sta. MCH No. 6 Ex P.G. and rotary burr No. 4318, No. 2 P.H. Rot. MCH No. 6 Ex P.G.) with a setting of from 5.0 to 5.5.

TABLE III

EFFECT OF EXTRACTION TIME AND TYPE OF GRIND UPON THE QUANTITY OF PIGMENT EXTRACTED FROM DURUM WHEAT SEMOLINA

Sample	Grind	Carotene p.p.m. (spectrophotometer) Time of extraction ½ hr.	1 hr.	2 hrs.	4 hrs.	16–18 hrs. (over night)	Remarks
Commercial No. 1	Wiley, ½ mm. screen	3.25	3.75	3.83	4.18	—	Standing [1]
		3.28	3.86	3.88	4.20	—	Shaken [2]
Commercial No. 1	Allis-Chalmers to unbolted flour	4.24	4.47	4.52	4.52	—	Standing [1]
		4.43	4.49	4.58	4.67	—	Shaken [2]
Commercial No. 1	Hobart [3]	—	—	—	—	3.88	Standing [1]
Commercial No. 1	Hobart [3] residue on 72 G.G.	—	—	—	—	3.70	Standing [1]
Commercial No. 1	Hobart [3] residue on 10 XX	—	—	—	—	4.08	Standing [1]
Commercial No. 1	Hobart [3] throughs 10 XX	—	4.62	—	—	4.62	Standing [1]

[1] Shaken by hand at commencement and end of test.
[2] Shaken mechanically throughout entire extraction period.
[3] Finest possible grind employing Hobart Model 6 burr mill (equipped with stationary burr No. 4317, No. 2 R.N. Sta. MCH No. 6 Ex P.G. and rotary burr No. 4318, No. 2 P.H. Rot. MCH No. 6 Ex P.G.) with a setting of from 5.0 to 5.5.

Studies were next conducted upon durum wheat semolinas and hard red spring and durum wheats, the results of which are detailed in Tables II and III. In the case of these materials, preliminary grinding is necessary and the selection of a suitable mill or grinding process represents the major difficulty in applying short-time extraction. In the instance of hard red spring wheat, a one-hour extraction appears to be adequate if the sample is either reduced to meal of flour-like fineness on an experimental mill or ground to pass a ½ mm. screen on the Wiley mill. When the Hobart grinder is employed, however, extraction is not complete in all cases even in four hours, although replicate tests at any given time are in excellent agreement. It will be noted that the Hobart grind, in the instance of the No. 1 Northern samples, is essentially constant at one-hour extraction, but this condition does not hold good for either the Garnet or durum wheats, which are of higher pigment content. Until a more satisfactory method of grinding is developed, it would appear desirable to utilize a longer extraction time for ground wheats or else determine the minimum time for the type of wheat under consideration. The results obtained with durum semolina are similar to those obtained with wheat; they emphasize the necessity of grinding to flour-like fineness if short extraction times are to be employed.

Clarification.—The production of a perfectly clear extract from flour suspensions has generally necessitated the use of a large-capacity high-speed centrifuge. Filtration through paper, alundum, or sintered

glass has been resorted to when such equipment was not available; in addition to the difficulty of securing clear extracts some adsorption of the pigment takes place when filter paper is used, as indicated by Ferrari and Bailey (1929).

TABLE IV

COMPARISON OF FILTRATION VS. CENTRIFUGING AS A MEANS OF CLARIFYING FLOUR EXTRACTS

	Carotene p.p.m. (spectrophotometer)
Original flour extract (centrifuged)	2.46
Extract filtered through a No. 1 Whatman paper	2.44
Extract filtered through a No. 2 Whatman paper	2.44
Extract filtered through a No. 4 Whatman paper	2.45

Sample No.		Carotene p.p.m. (spectrophotometer) Centrifuged		Filtered (No. 1 Whatman)	
		a[1]	b[1]	a[1]	b[1]
1	Exp. milled flour (unbleached)	3.05	3.05	3.05	3.05
2	Exp. milled flour (unbleached)	2.06	2.08	2.09	2.08
3	Com. milled flour (bleached)	1.86	1.86	1.85	1.87
4	Com. milled flour (bleached)	0.92	0.93	0.93	0.92

[1] Letters a and b represent duplicate tests.

The use of water-saturated n-butyl alcohol has been found to flocculate flour to a marked extent, thus enabling brilliant extracts to be obtained by simple filtration through paper; in addition the presence of water in the solvent might be expected to reduce adsorption. Studies were made to investigate this point and the data presented in Table IV clearly indicate that adsorption does not take place to a measurable extent. Furthermore, the flocculating effect is so marked that a wide range of filter-paper grades may be used with equally satisfactory results. From general considerations, however, a medium-speed paper of fair density, such as a No. 1 Whatman, should be selected.

Colorimetric estimation of pigment content.—In the instance of a simple method, the pigment content of the extracts is most conveniently determined colorimetrically by matching against potassium-chromate standards as outlined in the method of Geddes, Binnington, and Whiteside (1934) and also Cereal Laboratory Methods, Section III, 196, employing unfiltered mercury-arc radiation as an illuminant. Recent developments in the lamp industry have made available an inexpensive mercury-vapor lamp of high intensity operating upon alternating current through the medium of an auto-transformer. A light source of this type[4] has been employed by the authors for some time, replacing the more expensive quartz mercury-arc with entirely satisfactory results.

[4] General Electric Co. Type H-2 250-watt T-9 medium-screw 120-volt mercury-vapor lamp and No. 58G43 transformer.

Actual matching of the extracts is preferably carried out by the "Standard Series" procedure outlined by the above authors but a colorimeter of the Duboscq type may be utilized. For a limited amount of testing, a simple rack and reflector will suffice, although a device of the type described by Whiteside, Edgar and Goulden (1934) will be found very convenient if a large number of determinations are to be conducted.

Potassium-chromate standards.—Because of the different specific transmissive index of carotene in n-butyl alcohol as compared with naphthal-alcohol, the standards described by Geddes, Binnington, and Whiteside (1934) cannot be employed without recalculation of their carotene equivalents or revision of their concentrations. The latter course appeared preferable in order to provide a series corresponding to even units of carotene. These revised values have been computed and are presented in Table V for a range of 0.2 to 4.0 p.p.m. of carotene.

TABLE V

POTASSIUM CHROMATE REQUIRED TO PRODUCE STANDARDS EQUIVALENT TO 0.2 TO 4.0 PARTS PER MILLION CAROTENE (IN INCREMENTS OF 0.2 P.P.M.) IN FLOUR [1]

Carotene value	0.5% potassium chromate per 1,000 c.c.	Carotene value	0.5% potassium chromate per 1,000 c.c.
p.p.m.	*c.c.*	*p.p.m.*	*c.c.*
0.2	0.78	2.2	8.53
0.4	1.55	2.4	9.30
0.6	2.33	2.6	10.08
0.8	3.10	2.8	10.85
1.0	3.88	3.0	11.63
1.2	4.65	3.2	12.43
1.4	5.43	3.4	13.18
1.6	6.20	3.6	13.95
1.8	6.98	3.8	14.73
2.0	7.75	4.0	15.50

[1] Based on a sample-to-solvent ratio of 20 g. flour to 100 c.c. of a solvent consisting of water-saturated n-butyl alcohol.

In order to test the accuracy of the revised standards, the pigment contents of a series of 39 flours were determined by both the spectrophotometric and colorimetric methods, single determinations only being made. The results presented in Table VI and shown graphically in Figure 1 indicate the essential accuracy of the standards. With reference to the absolute accuracy of the colorimetric method, it should be pointed out that in such a method of comparison, the onus of all the errors involved is thrown upon the colorimetric method, as the spectrophotometer values are taken as standard. Our experience indicates that the accuracy of the spectrophotometric method is in the order of 0.02 to 0.04 p.p.m.; the colorimetric method may thus be considered

satisfactory for all classes of work which do not involve the utmost precision.

TABLE VI

COMPARATIVE VALUES FOR CAROTENE CONCENTRATION IN FLOUR AS DETERMINED BY THE SPECTROPHOTOMETER AND THE REVISED POTASSIUM-CHROMATE STANDARDS EMPLOYING *n*-BUTYL ALCOHOL AS SOLVENT

Sample No.	Spectrophotometer (*a*)	Colorimeter (*b*)	Deviation (*b*) − (*a*)	Sample No.	Spectrophotometer (*a*)	Colorimeter (*b*)	Deviation (*b*) − (*a*)
	p.p.m.	*p.p.m.*	*p.p.m.*		*p.p.m.*	*p.p.m.*	*p.p.m.*
1	3.01	3.03	+.02	21	1.28	1.25	−.03
2	2.78	2.77	−.01	22	1.04	1.05	+.01
3	2.91	2.87	−.04	23	1.31	1.23	−.08
4	3.19	3.27	+.08	24	0.87	0.95	+.08
5	2.21	2.23	+.02	25	1.06	1.10	+.04
6	2.12	2.15	+.03	26	0.80	0.93	+.13
7	2.07	2.05	−.02	27	1.00	1.00	.00
8	2.19	2.17	−.02	28	0.70	0.75	+.05
9	1.86	1.85	−.01	29	0.74	0.80	+.06
10	2.34	2.30	−.04	30	2.93	2.95	+.02
11	2.66	2.50	−.16	31	3.32	3.28	−.04
12	2.65	2.65	.00	32	2.36	2.35	−.01
13	2.66	2.70	+.04	33	3.33	3.35	+.02
14	2.61	2.55	−.06	34	3.69	3.75	+.06
15	2.85	2.85	.00	35	3.32	3.37	+.05
16	2.06	2.00	−.06	36	3.46	3.50	+.04
17	2.39	2.50	+.11	37	3.43	3.40	−.03
18	2.25	2.30	+.05	38	3.83	3.87	+.04
19	2.14	2.20	+.06	39	3.93	3.95	+.02
20	2.69	2.63	−.06				

Mean difference (b) − (a) = + 0.011 p.p.m.

Rapid colorimetric method for carotenoid pigments in flour.—The results of these studies, in which the colorimetric method described in Cereal Laboratory Methods has been modified to incorporate the rapid features made possible by the use of water-saturated n-butyl alcohol as solvent, are summarized below.

APPARATUS

(1) *Comparator (Nessler) tubes.*—Clear glass tubes with fused-on plane parallel bottoms, 150 mm. high, 24 mm. diameter, wall thickness approximately 1.5 mm. Graduation marks to be etched at 40 and 80 mm. measured from the inside of the bottom surface. Comparator tubes may be obtained from Eck & Krebs, 131 West 24th St., New York, U. S. A.

(2) *Color comparator.*—The color comparator comprises a quartz-mercury lamp (Alpine sun lamp or 250-watt mercury-vapour lamp similar to General Electric Company Type H–2) enclosed in a suitable ventilated housing, together with a rack for the comparator tubes and a magnesium oxide-coated reflector. The comparison rack may consist of a simple stand fitted with a clear glass shelf upon which the tubes may be arranged, with the reflector inclined at a suitable angle beneath, or the more elaborate apparatus described in Cereal Chem. 11: 615. Readings must always be taken by viewing vertically through the column of liquid.

REAGENTS

(1) *Water-saturated n-butyl alcohol.*—This solvent is prepared by shaking commercial n-butyl alcohol with an excess of distilled water. The mixture is allowed to stand until clear and the upper layer siphoned off for use. If the alcohol is not colorless it should be redistilled prior to saturation with water.

(2) *Stock potassium-chromate solution, 0.5%.*—Dissolve 5 g. potassium chromate (reagent grade) in distilled water and dilute to 1 liter. The quantities of this stock solution required to make one liter of each of the Standards are shown in Table V.

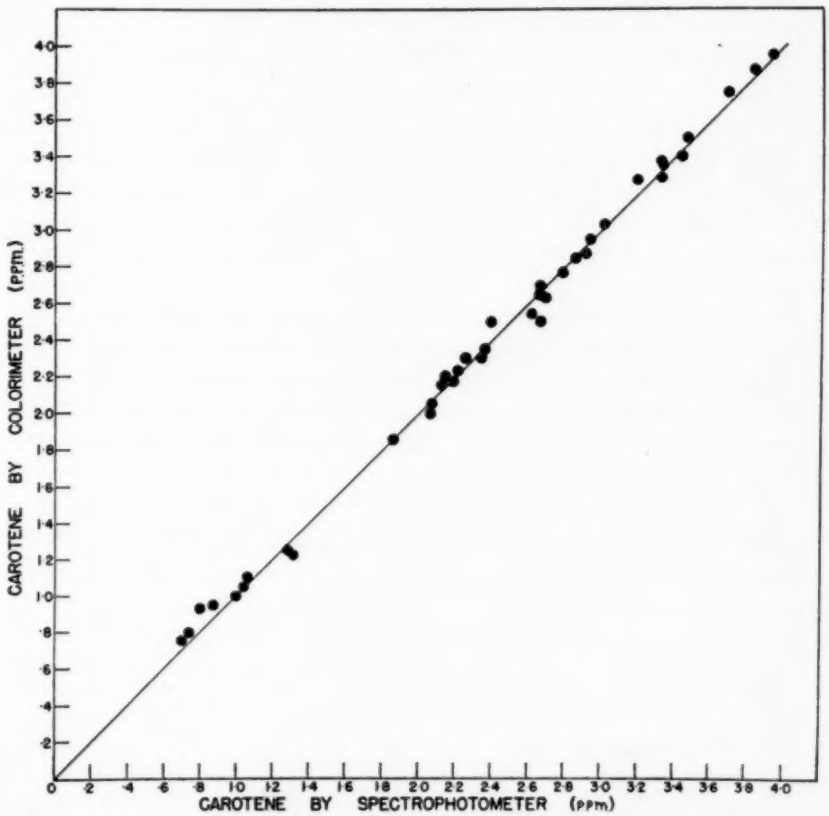

Fig. 1. Graph showing the relation between spectrophotometric and colorimetric carotene values using water-saturated n-butyl alcohol as solvent. Colorimetric determinations were made with the revised potassium-chromate standards.

Determination.—Weigh 20 g. flour, transfer to a 250 c.c. narrow-mouth glass-stoppered bottle and add 100 c.c. water saturated n-butyl alcohol from a pipette. The bottle is stoppered, well shaken, covered with a black cloth, and allowed to stand for 15 minutes. It is then reshaken and the contents filtered through a 15 cm. No. 1 Whatman paper, the filtrate being collected in a small beaker, flask, or stoppered bottle.

Comparison with the potassium-chromate standards is effected by viewing vertically through the columns of liquid, carotene being estimated to 0.05 p.p.m. or less. (This method is based upon the assumption that the pigments extracted are essentially carotenoid and hence expresses the content of total pigments in terms of carotene.)

Notes on the method.—It is not necessary to employ an analytical balance, as an accuracy of 0.01 g. is ample. Any balance of the so-called "laboratory" or "pulp" type possessing a sensitivity of 1 mg. will suffice.

If many determinations are to be made, a specially designed all-glass automatic pipette is desirable. However, the device described by Ferrari (1933), in which the solvent is forced upwards into the pipette by air pressure applied to the stock bottle is very satisfactory and can be readily improvised in the laboratory. Failing this, the pipette may be filled by suction from a water pump. For very rapid work where a moderate error is permissible, a 100 c.c. measuring cylinder may be employed.

All flour extracts, particularly those prepared from bleached flours, lose a certain amount of pigment even when stored in the dark. The magnitude of this effect may be judged from the data presented in Table VII and suggests that precautions should be taken to minimize exposure and also to avoid undue delay in reading the extracts.

TABLE VII

EFFECT OF TIME OF STANDING AND EXPOSURE TO DAYLIGHT UPON THE PIGMENT CONTENT OF FLOUR EXTRACTS

Time of exposure	Carotene content					
	Exp. milled light	Un-bleached dark	Com. milled light	Bleached dark	Com. bleached light	Bleached dark
Hrs.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
0	2.49	2.49	1.70	1.70	0.87	0.87
2½	2.38	2.47	1.39	1.65	0.70	0.85
5¼	2.24	2.39	1.32	1.60	0.68	0.78
Over night	2.16	2.39	1.29	1.58	0.64	0.78

In preparing the potassium-chromate standards, dilutions are best made with the aid of a 25-c.c. burette, the graduations of which are widely enough spaced to permit of estimation of 0.01–0.02 c.c. In the event that such a burette is not available, a satisfactory substitute may be improvised from a 10-c.c. or 25-c.c. Mohr pipette. Matching of the samples is best conducted in a darkened room, but this is not essential, provided the readings are made with mercury-vapor radiation *only*. With samples ranging up to 3.0 p.p.m., both standards and samples

should be set at a depth of 80 mm.; when the concentration exceeds 3.0 p.p.m. depths of only 40 mm. should be used and in excess of 4.0 p.p.m. it is preferable to dilute the extract with an equal volume of solvent.

The presence of water in the used butyl alcohol solvent offers no obstacle to recovery by simple distillation. Although the pure alcohol dissolves approximately 19.5% of its weight of water at room temperature, it forms a constant boiling mixture, boiling at 92° C. and containing 37% of water, which mixture on cooling separates into two phases. As the elimination of water from the mixture in the distilling flask proceeds, the temperature rises to the boiling point of the anhydrous alcohol (117.9° C.) and remains at this point until distillation is complete. It is then simply necessary to add a small excess of water to the distillate, shake thoroughly in order to insure complete saturation, and allow to stand until clear.

Discussion

The method described appears to fulfil all the necessary requirements of a rapid, simple, inexpensive procedure for the determination of carotenoid pigmentation in flour. A test can be carried through to completion in half an hour and one operator can conduct 30 or more tests per day. No special equipment other than the mercury-vapor lamp and colorimeter tubes is necessary. In the instance of semolina and wheat, however, the rapidity of the method is conditioned by the grinding facilities available and further investigation is needed before a short-time extraction can be definitely specified for such products. The accuracy of the method compares favorably with the overnight extraction procedure and should be adequate for all but the most precise studies.

Summary

A rapid, simple, inexpensive colorimetric method for the determination of flour pigments based on the use of water-saturated n-butyl alcohol as a solvent is outlined.

It is shown in the instance of a number of different types of flours that fifteen minutes of extraction yields the same results as overnight treatment. A somewhat longer extraction (1 hour) is adequate for semolina and ground wheat, *provided* the sample is reduced to flour-like fineness. With this type of material grinding is the critical factor and samples ground with the conventional types of equipment require 4 to 16 hours for maximum extraction.

Clarification of the extracts may be accomplished by filtration through paper rather than by use of the centrifuge, as no appreciable adsorption of pigment takes place and the flocculating effect of the

water-saturated solvent upon the flour particles yields extracts of extreme brilliance.

Directions are given for the preparation of a series of potassium-chromate standards equivalent to a range of from 0.2 to 4.0 p.p.m. of carotene. These values are based on the use of water-saturated n-butyl alcohol as solvent, a sample-to-solvent ratio of 20 g. to 100 c.c., and the use of unfiltered mercury-vapor-lamp radiation as an illuminant. The reliability of these standards has been checked against the spectrophotometer in the instance of 39 samples of flour and found to be satisfactory. An inexpensive mercury-vapor lamp and accessory equipment are suggested.

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PRACTICAL APPLICATION OF THE A. A. C. C. BAKING TEST [1]

MAX C. MARKLEY

Cargill, Inc., Minneapolis, Minn.

(Read at the Annual Meeting, May 1938)

The A. A. C. C. baking test, or the "pup" test as it is commonly called, is an excellent base on which to develop practical methods of evaluating the baking qualities of wheats of many types. The test itself as outlined in the manual is hardly suited to routine testing in the commercial laboratories, but it serves as an excellent point of departure. Last year at the Minneapolis convention I presented a series of models showing the effect of simultaneously varying both the

[1] Sub-committee report, 1937–38 Committee on Standardization of Laboratory Baking.

mixing time and the fermentation time. This called for the baking of from 9 to 12 loaves from each sample of flour, which is impractical for routine testing. I am now presenting a modification of the variable method which I have found well adapted to the routine testing of flour samples of widely varying strengths.

I have retained the basic formula with the exception that the sugar is raised to 5%. Double the standard charge is weighed out. The absorption is varied with the protein content of the flour. This is in accord with the findings of Markley and Bailey (1938) in studies of dough formation in a recording dough mixer. A flour of 9% protein normally receives about 50% water, while one of 13% would get 62.5%. Occasionally a flour is found which requires more or less than the average for the protein content.

The mixing is carried out in the three-quart bowl of a Hobart mixer equipped with a paddle blade. The mixer is operated on slow speed for one-half minute to form the dough ball. When hard wheat flours are being mixed, the machine is then shifted to high speed and allowed to run until the doughs "clean up" or come free from the sides and start riding the paddle. The time required for this "clean-up" has been found to be quite highly correlated with the protein content. A low-protein hard-wheat flour will usually be well developed after one minute of high-speed mixing, while the high-gluten types may require 2½ minutes. Soft-wheat flours are mixed at medium speeds since they tend to become overdeveloped at high speeds before the dough is smooth.

After mixing the dough is placed in a two-pound butter crock. The standard bowl is too small for doughs from 200 g. of flour. The fermentation cabinet is held at 30° C. After 90 minutes of fermentation the dough is scaled into two 150-g. portions. One is returned to the cabinet and the other is panned. A standard high-form pan is used. It is proofed and baked according to the official method. The other portion is panned after 180 minutes of total fermentation. A second punch is given 20 minutes before panning. It is proofed and baked in the same manner as the first portion.

Variations are regularly introduced as supplements. Malt preparations, oxidizing agents, yeast foods, and improvers can be added to the basic formula. Other fermentation times and mixing times are occasionally useful. This test works well in determining the blending properties of flours.

It may be argued that it is not justifiable to compare loaves from different flours when the doughs have not been given exactly the same mixing time, but it appears more logical to use a biological criterion of mixing time, such as the "clean-up" in the Hobart mixer or the

"sheeting" in the Swanson machine, rather than arbitrary units of time. In all biology it is very rare to find any process which runs exactly by the clock, and a dough is certainly a biological substance. Not only is the mixing time varied in this method of baking, but also the absorption is varied simultaneously with both the mixing time and the protein content. This is in accord with the findings of Markley and Bailey that there is a high inter-correlation between these three factors. This work indicates that both the absorption and the mixing time should be varied with the protein content if the doughs are to be mixed to the same stage of development. If doughs are not brought to the same stage of development it is unjustifiable to compare the finished loaves when flours are being evaluated. In the test method I find that an 11% protein flour at 57½% absorption is developed by one-minute of high-speed mixing to the same stage that a 13% flour is at 62½% absorption and two minutes of high-speed mixing.

The use of the uniform dough weight instead of uniform flour weight in each loaf is another of the long-debated points in test-baking technology. I recognize that the spread between flours in loaf volume tends to be narrowed when a uniform dough weight is used, but on the other hand it avoids the setting up of false differences between flours. The false differences, which are often found when the standard flour weight is used, are the cause of many of the discrepancies between the laboratory results and the findings when the flour is baked in the big shop.

This method of adapting the basic test to practical use appears to be advantageous in several ways. It is economical of flour, which is an advantage when experimentally milled flours are to be tested. Doughs are all given a uniform start by bringing them out of the mixer at uniform mobility and uniform stage of development. This makes the results quite comparable regardless of the strength of the flour. On this basic test many supplements can be superimposed.

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THE COLLOIDAL BEHAVIOR OF FLOUR DOUGHS. V. COMPARISON OF THE INCREASE IN MOBILITY OF DOUGHS UPON EITHER PROLONGED MIXING OR FERMENTATION WITH THE EFFECTS OF VARIED MIXING TIMES UPON LOAF CHARACTERISTICS [1]

M. C. MARKLEY and C. H. BAILEY

Division of Agricultural Biochemistry, University of Minnesota, St. Paul, Minnesota

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American cereal chemists have been long accustomed to using the baking test as the final criterion of flour quality. Any mechanical device which is offered as a substitute for the baking test must yield values which show a high correlation with baking results if it is to be generally adopted in America (Geddes, Larmour, and Mangels, 1934). The Brabender-Hankoczy farinograph, from the claims made by its makers and from reports of European cereal chemists, appeared to have potentialities for the differentiation of wheat varieties, which is one of the major interests of the cereal laboratories of the Minnesota Agricultural Experiment Station.

The baking method used in these laboratories for variety testing was essentially Supplement D of the basic baking procedure of the American Association of Cereal Chemists. This supplement involved the variation of mixing time. With the spring-wheat flours mixing times of 2 and 5 minutes in the Hobart-Swanson mixer were employed. Enough malted wheat flour, approximately 1%, was used in order that no sample would suffer from diastase deficiency in the baking test. The farinograph, which records the changes in mobility of doughs during a prolonged mixing period somewhat similar to that given the doughs in the Hobart-Swanson instrument, possibly would give the same information as the mixing differential baking test.

In order to test this hypothesis a series of 23 spring-wheat patent flours milled in the Pillsbury 50-bbl. testing mill from the wheats grown in the Northwest Crop Improvement Association trials during the crop season of 1933 were baked by this differential mixing procedure and also were tested in the farinograph. The method with the farinograph was to mix doughs with 300 g. of the flours (13.5% moisture basis), 9 g. of yeast, 3 g. of salt, and 7½ g. of sugar with sufficient distilled water to yield doughs of a minimum mobility of 550 ± 25 Brabender units at 30° C. The mixing period was prolonged to 40

[1] Paper No. 1610, Journal Series, Minnesota Agricultural Experiment Station.

minutes. The original titration curves (Brabender, 1932) were discarded and only smooth curves used in the study. After the mixing curve had been secured, a fermentation curve was made. The fermentation curve was identical with the mixing curve up to the time the dough reached the point of minimum mobility when the motor was cut off. The dough was allowed to rest for an hour in the mixer bowl at 30° and then the mixer was again put into motion. This second mixing was continued until the dough either recovered and passed through a new minimum or definitely did not recover. This was repeated hourly as long as desired. Examples of these two types of curves are given in Figure 1.

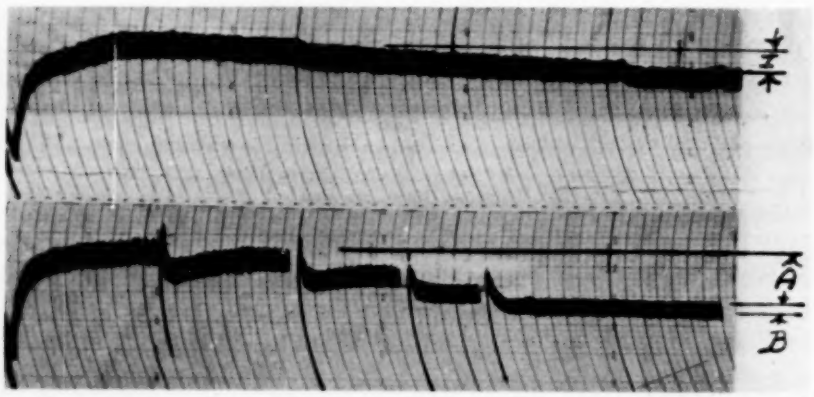

Fig. 1. Farinograms showing (above) an uninterrupted mixing curve; and (below) a curve of a dough mixed with the same flour to the point of minimum mobility, then allowed to ferment, and then remixed at intervals of one hour for a period of four hours.

The presentation of all the individual scores for the many baking tests and farinograph charts would be of doubtful service and require much space, and so merely the means, standard deviations, and coefficients of variation are presented in Table I.

All but one of the samples represented commercially grown varieties, and the geographical distribution was fairly representative of that of the 1933 spring-wheat crop. Accordingly these 23 flours may be considered a representative sample of spring wheats and exhibit about as much variation as was encountered in that season. Of all the scores included in Table I only the absorption as determined by the farinograph was low in variability. There was as much differentiation in protein content as is usually met with in any one crop year. The mixing-stability score was calculated by dividing a composite quality score for the loaves from doughs mixed 5 minutes by the scores for the loaves from doughs mixed for 2 minutes. This quality score is based upon loaf volume, crumb grain, crumb texture, and external appearance of the loaf.

TABLE I

STATISTICAL CONSTANTS FOR SPRING-WHEAT VARIETY PATENT FLOURS, 1933 CROP

		Mean	S.D.	C.V.
	Baking Scores			
C	Loaf volume, 2 min. mixing *c.c.*	598.3	79.0	13.2
K	Loaf volume, 5 min. mixing *c.c.*	522.4	54.1	10.4
E	Mixing-stability score [1]	81.1	14.5	17.9
	Farinograph Mixing Scores			
M	Absorption at 550 b.u. %	58.8	2.4	4.1
I	Gain in mobility at 40 min. *b.u.*[2]	97.0	22.0	22.7
	Farinograph Fermentation Scores			
A	Total gain in mobility in 4 hrs. *b.u.*	185.4	32.1	17.3
B	Recovery in mobility at 4 hrs. *b.u.*	19.5	17.8	91.2
L	Gain in mobility due to fermentation only (A–I) *b.u.*	88.5	25.3	28.6
	Analytical Data			
J	Protein in flour %	14.0	1.3	9.3
G	Diastatic activity (B and S) *r.u.*[3]	253.5	28.9	11.4
	n = 23			

[1] Mixing stability score $= \frac{.1\ (\text{loaf vol.} - 200) + 2 \times \text{grain} + \text{texture} + \text{type for 5-min. mix}}{.1\ (\text{loaf vol.} - 200) + 2 \times \text{grain} + \text{texture} + \text{type for 2-min. mix}}$.
Grain, texture, and loaf type scored on scale of 0 to 10.

[2] *b.u.* = Brabender units, representing actual *decrease* in scale reading which involves an *increase* in mobility.

[3] *r.u.* = Rumsey units.

The coefficients of correlation for all possible combinations of these variables are given in Table II. The coefficients which exceed the 5% value for significance are printed in italics. From an inspection of this table it can be noted that the loaf volumes of the 2-minute-mix method were highly correlated with the protein content of the flour, but were

TABLE II

COEFFICIENTS OF CORRELATION OF BAKING, FARINOGRAPH, AND ANALYTICAL SCORES

	K	E	M	I	A	B	L	J	G
C	*+.49*	*−.50*	+.35	+.12	−.27	*+.62*	−.24	*+.82*	+.01
K	—	+.29	+.08	−.09	−.02	+.09	−.08	+.33	−.19
E	—	—	−.26	+.10	+.11	*−.53*	+.22	*−.49*	−.19
M	—	—	—	+.13	−.02	*+.45*	−.13	*+.49*	*+.48*
I	—	—	—	—	*+.62*	−.20	−.08	+.01	+.26
A	—	—	—	—	—	−.33	*+.73*	−.25	+.38
B	—	—	—	—	—	—	−.08	*+.49*	*+.52*
L	—	—	—	—	—	—	—	−.33	+.25
J	—	—	—	—	—	—	—	—	−.07

n = 23 5% point = .41

independent of the diastatic activity. The volume of the 5-minute-mixed loaves was not significantly correlated with either the protein or the diastatic activity of the flour. The correlation between loaf volumes by the two methods, while significant, was not high. The mixing-stability score, which was calculated from the quality score for

5-minute-mixed loaf divided by quality score for 2-minute-mixed loaf, was negatively correlated with both 2-minute loaf volume and protein. Thus it appears that the relative damage to bread quality upon overmixing is the greatest in high-protein doughs.

This has been a frequent observation when using the mixing-time differential in the Hobart-Swanson mixer, although it is the reverse of what was commonly anticipated. The reason may be that there is more smoothing and compacting of the thick protein envelope about the starch granules than of the thinner envelopes in doughs of lower-protein flour. The absorption as determined in the farinograph is only moderately correlated with the protein content of the flour. The coefficient of correlation $r = +.49$ is low because of the small variability in water-absorbing power of the flours used in this study, the coefficient of variability being only 4.1% and the range 9%. The gain in mobility of the dough during mixing, which is the mobility reading at 40 minutes subtracted from the minimum reading, was correlated with neither the 5-minute loaf volume nor the mixing-stability score. Neither was it correlated with either protein content or diastatic activity. It appears to be independent of those factors which we normally associate with bread-quality damage.

One explanation for the lack of a correlation between the increase in mobility of a dough upon overmixing and the damage to the finished loaf resulting from overmixing lies in an observation frequently made by baking technicians that often a dough which is very soft and ductile at the time of stopping the mixer quickly becomes stiff and short upon resting. This property is probably a starch function since it was shown in the first paper of this series (Markley, 1937a) that starch-water pastes in the dough range of mobility are thixotropic, having a gel structure when quiescent and becoming a sol upon agitation. The uniformity of the starches from different lots of wheat with regard to mobility of stiff pastes has never been investigated; it is possible that there may be much variation in this property.

Another explanation for the lack of correlation between the increase in mobility upon overmixing in the farinograph with the damage to bread by the same process may lie in the limitations of the baking test. The two mixing times, 2 and 5 minutes, were arbitrarily chosen without regard for the differences in time of development for the individual flours. Markley (1937b) has shown that with short fermentation times the loaf quality increases as the mixing of the dough is increased up to the limits of handling ability, while with long fermentation times the loaf quality generally decreases as mixing time is increased, the exact conditions being functions of the quality of the individual flour being tested. It is probable that the arbitrary mixing times of 2 and

5 minutes used in this study had no constant relation to the physical condition of the various doughs studied. If the mixing for the baking tests had been carried out in the farinograph, using the time to the minimum mobility of the dough and a definite increase in mobility, there might have been some relation between the shape of the farinograph curves and the results of the Supplement D as based upon a biological rather than a timed mixing differential.

It is probable that both of these explanations enter into the picture. It would be presumptuous for us to condemn arbitrarily a testing procedure merely because it does not conform to our present baking technique, which though useful is yet far from being a complete and perfect test. It appears certain that the observations made by means of the farinograph, and probably all other similar recording dough mixers, give us information which is distinct from that given by Supplement D (variation of mixing time) of the A. A. C. C. basic baking procedure. This lack of agreement does not condemn as worthless such physical techniques; they give very valuable supplementary information which is of value in determining how a flour will behave in the machines of the shop. A single baking test gives us practically no precise information on this point.

The fermentation curves as illustrated in Figure 1 indicate the extent to which dough mobility changes during fermentation. This is of special value to the baker as it lets him know for example just when a dough can no longer be worked without damage. The measurement of the increase in mobility at 4 hours (A) is the difference between the minimum mobility and the mobility at the secondary minimum at 4 hours if such appears, or is the mobility at 2 minutes if the mobility continually increases without the temporary decrease. The amount of this secondary decrease in mobility or increase in viscosity (B) was measured from the inflection point to the secondary point of minimum mobility.

The gain in mobility during 4 hours of fermentation (A in the tables) was not correlated with the baking scores, but was correlated with the increase in mobility due to overmixing (I). The correlation of $r = +.38$ for diastatic activity (G) and the fermentation increase (A) approached statistical significance, and possibly may reflect the action of the α-amylase upon the starch. The correlation between the fermentation increase (A) and the mixing increase (I) may be questionable since there was much additional mechanical energy put into the system during the hourly workings. With this point in mind the values for mixing increase (I) were subtracted from those values from the fermentation curves (A), with the resulting increases (L) due solely to the effects of fermentation. The values for L were found to be

independent of those for I, which indicates that the changes in the mobility of doughs upon fermentation are caused by factors other than those responsible for the slackening during prolonged mixing.

The shape of the hourly mixing curves resemble the thixotropic starch curves presented in the first section of this report. The rising of the curve due to redevelopment of the gluten is foreign to the starch curves, but after long fermentation the shape is identical with the starch type. There is one important difference between the starch and the fermentation curves in that the starch curves tend to repeat indefinitely the same mobility values, while the flour doughs continually increase in mobility from one hour to the next. Probably any or all of the many causes for the increase in mobility of the overmixed doughs as discussed by Markley (1937b) may enter into the fermentation increase, though not in the same proportions as in overmixing. In this group may be included mechanical damage caused by the gas expansion, proteolytic action, α-amylase action, and any other type of damage.

The amount of the secondary decrease in mobility in the fermentation curve may be of importance. It (B) was positively correlated with the protein content, the 2-minute loaf volume, and the absorption, and was negatively correlated with the mixing-stability score (E). This may be interpreted as implying that high-protein flour doughs have enough gluten so that after four hours of fermentation they can be partially rebuilt in mobility and that such flours will yield the best bread. This recovery may be an elastic effect, since its decay during fermentation follows the rate of decay of elasticity as shown by Bohn and Bailey (1937).

Summary

Increase in mobility of doughs upon prolonged mixing was not significantly correlated with the decrease in bread scores resulting from similar treatment, nor with the increase in mobility due to prolonged fermentation in the instance of doughs prepared from a series of 23 spring-wheat flours of the 1933 crop.

Increase in mobility of a dough upon proloned mixing may be significant in the practical handling of doughs prepared from the same flour in a commercial shop when these relations are sufficiently established for the mixer and other mechanical facilities of the shop in question.

Conventional baking tests frequently are not designed for the adequate determination of mixing effects.

Temporary partial reconstruction of the fermenting dough upon reworking is apparently related to the production of optimum bread.

Acknowledgments

The authors wish to acknowledge the work of Mr. F. L. Harrington in operating the farinograph and of Mr. W. Dugas in measuring the many charts. They also wish to express their appreciation of the grants of funds from the CWA, the SERA, and the NYA, which made possible the carrying out of this entire project.

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THE COLLOIDAL BEHAVIOR OF FLOUR DOUGHS. VI. DOUGH FORMATION FROM FLOURS OF DIVERSE TYPES [1]

M. C. MARKLEY, C. H. BAILEY, and F. L. HARRINGTON

Division of Agricultural Biochemistry, University of Minnesota, St. Paul, Minnesota

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In the earlier papers of this series, certain basic principles involved in the application of recording dough mixers to dough fermentation have been discussed (Markley, 1937, 1938; Markley and Bailey, 1938). It appeared highly desirable to test these findings upon an extensive series of flours of diverse types. To this end a series of 89 flours was collected from many sources during the spring of 1934. These 89 flours included a group of experimentally milled Canadian protein composite flours from the Dominion Grain Research Laboratory, a series of commercially milled spring wheat flours from variety trials, a typical collection of Southwestern hard winter wheat flours of all grades, and a wide assortment of soft wheat flours, including four typi-

[1] Paper No. 1615, Journal Series, Minnesota Agricultural Experiment Station.

cal German flours. All samples were analyzed for moisture and protein.

Doughs were mixed from each of these flours in the farinograph, very rigid conditions being prescribed and maintained. All doughs were made from 300 g. of flour at 13.5% moisture. The basic baking formula of the A. A. C. C. was employed for this study, which included 3% yeast, 2½% sugar, and 1% salt. Sufficient water was employed to yield doughs with minimum mobilities of 550 ± 25 units. Dough temperatures were held between 29° and 30° C. Under these conditions the quantity of water used (corrected to the 13.5% flour moisture basis) may be considered to be a function of the viscosity or mobility of the freshly mixed doughs, and the time required for the various doughs to reach the point of minimum mobility becomes a significant characteristic.

While Swanson (1936) in the study of flours of diverse strengths preferred to use the supercentrifuge method of determining the proper absorption, yet in the light of the findings in the earlier portion of this study (Markley, 1937a) such a method did not appear justified. If the supercentrifuge method had been used for the determination of absorption, then there would have been a wide variation in the minimum mobility of the dough likewise, as is evident from Swanson's graphs, and a corresponding wide variation from commercial practice. It would have been impossible, also, to obtain comparative data respecting the time required to properly mix doughs prepared from the different flours.

On the other hand if the same quantity of water had been used with all flours there would have been difficulty in selecting a single absorption which would have yielded doughs possessed of mobilities within the range of the farinograph. Moreover, such doughs would have varied in mobility above and below that which is customary in commercial baking practice.

The farinograph records were used, therefore, as the measure of absorption. After a preliminary or exploratory titration test of absorption, smooth dough-development curves were traced by the farinograph. These were carefully measured for mobility at the end of five-minute intervals, and at the minimum point as well. The time in minutes required to reach the minimum mobility was also recorded, and the width of the line was noted for each such measurement. Certain of the significant data from these measurements, and the crude protein content (N × 5.7) are recorded in Table I. These data were also included in the statistical analysis.

The relation between absorption and protein content is shown graphically in Figure 1. The coefficient of correlation for these two

facts for the entire group was found to be $r_{AE} = +0.71$. Among the subgroups, it rose to the highest level, $r_{AE} = +0.99$, in the instance of the Canadian flours and fell to the lowest level, $r_{AE} = +0.48$, in the case of the Northwestern hard spring wheat flours. It is of special interest to note the lack of differentiation between the hard and soft wheat flours. Where there was similar protein content of the two types there did not appear to be any difference in absorption. There

TABLE I

PROTEIN CONTENT AND FARINOGRAPH SCORES OF SAMPLES USED IN DOUGH FORMATION STUDY

Variety or grade	Source	Protein %	Absorption %	Minimum mobility B.U.	Time to point of minimum mob. *min.*
Canadian Protein Composite Series, 1935 Crop					
Exp. St.	Canada	11.4	55.5	555	7.2
"	"	11.8	56.0	545	10.0
"	"	12.3	56.5	560	9.0
"	"	12.8	57.5	545	10.0
"	"	13.1	58.0	575	9.7
"	"	13.6	58.0	560	12.0
"	"	14.2	59.0	575	8.7
"	"	14.7	60.0	555	14.5
"	"	15.4	61.0	550	14.2
"	"	15.7	62.0	555	17.0
Miscellaneous Spring Wheat Flours					
Patent	Minnesota	12.1	56.3	560	9.0
"	"	13.3	60.0	560	10.2
Straight	"	15.4	61.0	565	12.2
1st Clear	"	13.5	61.0	545	13.5
Experimentally Milled Spring Patents, 1934 Crop					
Marquis [1]		14.5	61.0	535	15.5
Ceres [1]		15.0	65.0	590	13.2
Hope [1]		15.7	60.5	560	15.0
Reward [1]		15.9	62.5	550	14.0
Thatcher [1]		16.1	61.5	555	15.0
H-44 × Marquis [1]		14.4	62.0	570	15.2
No. 2315 [1]		16.0	62.0	560	14.0
Marquis [2]		10.1	57.5	545	5.0
Ceres [2]		11.3	61.0	560	8.0
Hope [2]		11.8	59.0	550	10.0
Thatcher [2]		11.8	59.5	560	10.7

[1] Blends of equal parts wheat from St. Paul, Waseca, and Crookston, Minn.
[2] Blends of equal parts wheat from Grand Rapids and Duluth, Minn.

TABLE I—*Continued*

Variety or grade	Source	Protein %	Absorption %	Minimum mobility B.U.	Time to point of minimum mob. *min.*
		N. W. C. I. A. Spring Wheat Patents			
Marquis	Fessenden, N. D.	13.6	60.0	540	9.5
Ceres	" "	14.0	62.7	575	10.5
Reward	" "	14.4	60.0	535	15.0
Marquis	Leeds, N. D.	13.5	58.3	540	12.2
Ceres	" "	14.6	62.0	570	9.2
Reward	" "	14.6	61.3	540	12.7
Marquis	Fargo, N. D.	13.7	57.2	560	10.0
Ceres	" "	15.1	64.3	560	10.2
Reward	" "	15.2	57.3	565	14.0
Thatcher	" "	14.5	60.7	555	10.0
Marquis A	Benton, Mont.	12.3	56.7	540	11.5
Ceres A	" "	11.6	58.7	530	10.0
Thatcher A	" "	13.2	56.3	540	11.5
Supreme A	" "	12.7	55.3	545	9.5
Comet A	" "	12.3	54.3	575	8.7
Marquis	Crookston, Minn.	11.8	57.7	540	8.0
Thatcher	" "	13.4	57.3	565	9.0
Marquis	Montevideo, Minn.	15.1	59.3	570	9.5
Thatcher	" "	17.0	57.7	560	13.0
Marquis	Morris, Minn.	14.8	59.0	560	11.0
Thatcher	" "	16.0	62.0	570	11.2
Marquis	Waseca, Minn.	13.3	56.0	550	8.0
Thatcher	" "	14.6	57.0	550	10.0
		Commercially Milled Hard Winter Flours, 1933 Crop			
Patent	Kansas	10.8	61.5	535	8.5
Clear	"	12.9	63.0	550	9.5
Patent	"	11.3	62.0	550	7.7
1st Clear	"	13.0	63.0	560	9.2
2nd Clear	"	15.3	66.5	560	10.8
Patent	Missouri	10.1	56.0	540	7.6
Clear	"	11.1	57.0	530	8.7
Patent	"	11.7	57.0	535	7.0
Clear	"	13.1	60.0	555	8.7
Patent	Texas	10.9	58.0	535	9.7
Clear	"	12.8	58.0	560	9.7
Patent	"	11.5	58.0	570	7.7
Clear	"	13.5	61.5	570	11.7
Patent	Kansas	10.4	58.0	555	6.5
Clear	"	12.2	60.0	550	8.2
Patent	"	11.4	60.0	550	9.2
Clear	"	13.9	63.0	565	11.0
Patent	"	11.8	61.0	545	8.2
Clear	"	14.4	63.5	535	10.5
Straight	Missouri	10.1	56.0	570	6.7
Patent	Kansas	11.0	56.0	560	7.5

TABLE I—*Continued*

Variety or grade	Source	Protein %	Absorption %	Minimum mobility B.U.	Time to point of minimum mob. *min.*
		Commercially Milled Soft Wheat Flours			
Short Patent	Indiana	7.7	48.5	520	2.0
" "	Illinois	7.6	50.2	535	2.0
" "	"	7.9	49.1	550	3.5
" "	"	8.5	50.0	540	3.7
" "	Utah	7.5	50.0	550	2.2
" "	Missouri	9.3	53.0	555	3.7
Long Patent	"	9.6	53.0	560	3.5
Clear Patent	"	10.3	54.5	520	6.0
Long Patent	Kentucky	9.2	52.0	550	4.5
Patent	"	9.2	53.5	555	7.2
Clear	"	10.4	57.5	535	7.7
Hd. W. Pat.	Washington	11.4	56.5	500	5.0
Hd. W. Clear	"	14.2	63.0	535	7.2
Club Pat.	"	7.2	48.0	535	1.2
Club Clear	"	8.7	53.0	550	2.2
Patent	Germany	8.4	50.0	530	3.0
Clear	"	9.2	51.5	575	3.2
Baker's Pat.	"	9.9	55.0	565	6.0
Baker's Clear	"	10.8	57.5	545	4.5

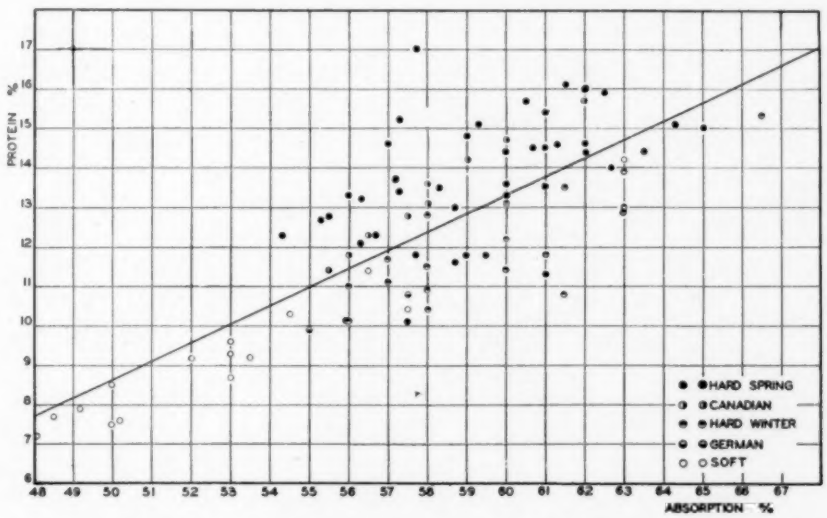

Fig. 1. Relation between the protein content of diverse flours and the absorption or the amount of water required to form doughs of a definite minimum mobility.

was some deviation from the fitted line, however. Those flours having absorptions lower than that predicted from their protein content, had, in this particular property of water-imbibing power, an inferior gluten quality, while those with higher absorptions had a superior gluten in at least that particular. This correlation suggests that instead of leaving the estimation of absorption for the basic baking test to the judgment of the operator, it might well be made a function of the protein content, with any necessary deviations from the average being considered as measures of deficiency or superiority in absorption. By this method the effect of protein quantity would be divorced from that of quality, which is a much needed addition to our test baking procedure.

TABLE II

COEFFICIENTS OF CORRELATION BETWEEN FACTORS IN DOUGH FORMATION

	AB	*CD*	*AE*	*BE*	Number of samples	5% pt.	1% pt.
Entire series	+.71	−.82	+.77	+.88	89	.24	.27
Soft wheat flours	+.78	−.78	+.96	+.75	19	.53	.58
Hard winter flours	+.67	−.67	+.80	+.80	21	.50	.55
Northwestern hard spring flours	+.44	−.43	+.48	+.67	39	.38	.42
Canadian flours	+.88	−.86	+.99	+.85	10	.72	.76

A—Absorption (water required per 100 g. flour at 13.5% moisture to yield dough having a minimum mobility of 550 ± 25 units.

B—Time in minutes required to develop doughs to minimum mobility.

C—Flour concentration in dough—grams per 100 g. water.

D—Logarithm of time in minutes required to develop dough to minimum mobility.

E—Crude protein content of flour (N × 5.7).

The time required to bring the doughs to their minimum mobility of 550 B.U. was found to be highly correlated with the protein content of the flour; the coefficient being $r_{BE} = + 0.88$, which is a very good agreement. The scatter diagram with the fitted line is shown in Figure 2. This is in close agreement with the findings reported earlier (Markley, 1938) upon the flour-starch-water doughs. On the basis of this study it is proposed that a more logical mixing treatment for the basic baking test than the present one of an arbitrarily fixed time would be a sliding scale of mixing times based upon protein content as derived from the average results of a great many flours. From the estimate of Bohn and Bailey (1936) that five minutes of mixing in the farinograph is approximately equal to one minute in the Hobart-Swanson it would appear that flours of 10% protein would be mixed to about their optimum by the basic baking procedure, while flours of lower protein content would be overmixed and the high-protein

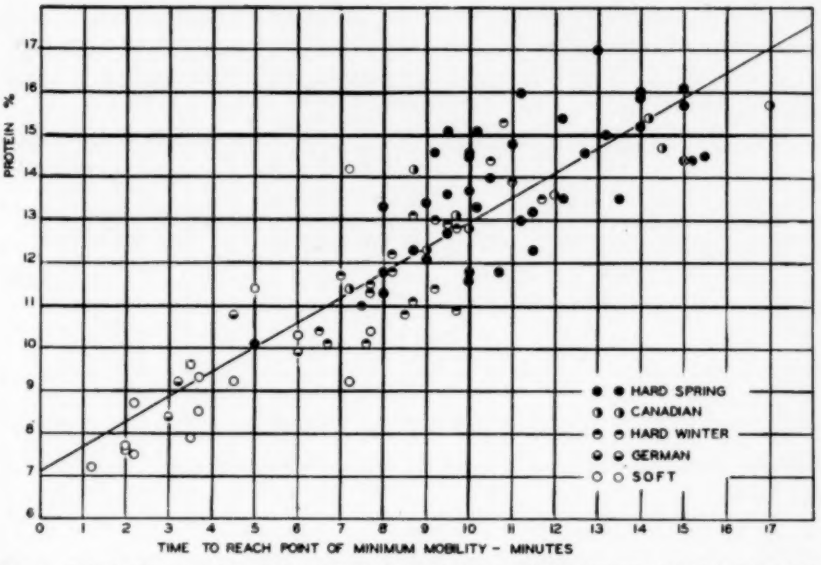

Fig. 2. Relation between the protein content of diverse flours and the time required to develop these flours into doughs of definite minimum mobility.

flours would be seriously undermixed. The soundness of the philosophy underlying the fixed mixing time is very questionable.

In Figure 3 are shown the relations between absorption and time required to bring the doughs to the constant minimum mobility in the farinograph for the different classes of flours. For the entire series the coefficient of correlation is $r_{AB} = +0.71$, and the individual classes range from $r_{AB} = +0.88$ down to $r_{AB} = +0.44$. On the whole this relation appears to be curvilinear, so the values were recalculated as in section II (Markley and Bailey, 1938) to the basis of grams of flour per 100 grams of water and the log of the time. This

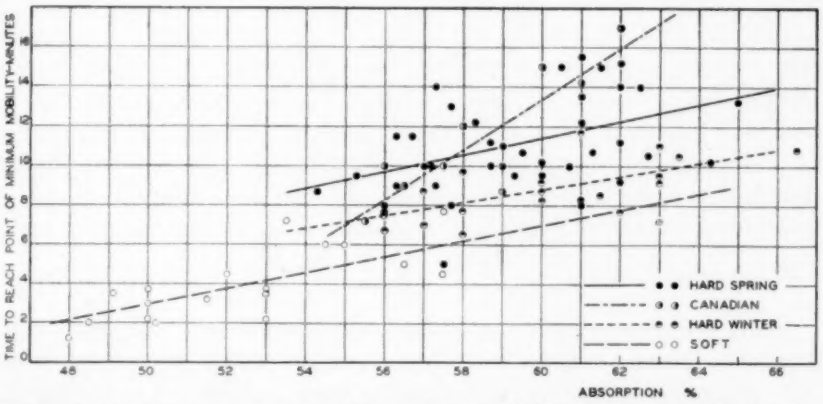

Fig. 3. Relation between the absorption of diverse flours and the time required to develop them into doughs of definite minimum mobility.

calculation straightened out the line, as may be seen in Figure 4. The coefficient of correlation for the series by this procedure was raised to $r_{CD} = -0.82$. There is good agreement with the earlier findings upon a few flours.

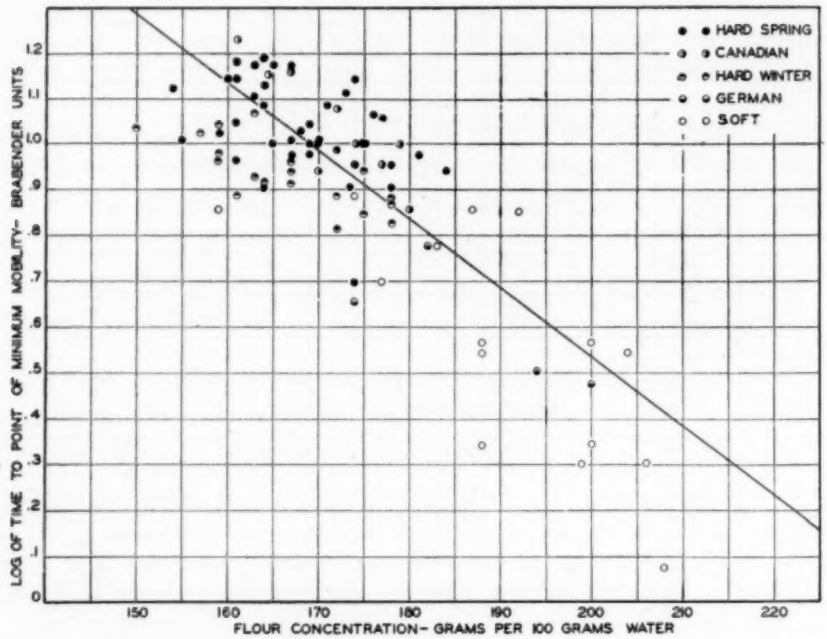

Fig. 4. Relation between the concentration of flour in doughs of definite minimum mobility with the log. of the time required to develop the dough.

The discovery of the close interlocking of protein content with both absorption and development time for doughs made from such a diverse group of flours as those used in this study opens a new approach towards standardizing the baking test. Thus it would be desirable to measure this relationship for a great many more flours from several crop seasons, and from the resulting mass of data secure accurate mean absorptions and mixing times for each protein level, using protein classes involving a range not greater than one percent. Then when a flour is found that deviates from this average in absorption and mixing time (either or both), as would many of the 1936 crop flours, it would be possible to report both an absolute value and a quality value for each factor.

Summary

Dough formation in an extensive and diverse series of flours was studied. Protein content was found to be highly correlated with absorption and with dough-development time. Absorption was highly

correlated with development time. A scientific basis for a standardization of certain details of the baking test is suggested.

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A STUDY OF GLUTEN PROTEIN FRACTIONATION FROM SODIUM SALICYLATE SOLUTION. PART IV. EFFECT OF PROTEOLYTIC ENZYMES, AS INFLUENCED BY CLASS OF WHEAT

R. H. HARRIS and JOHN JOHNSON, JR.

North Dakota Agricultural Experiment Station, Fargo, North Dakota

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It is evident from a study of the literature that there is a diversity of opinion among cereal chemists respecting gluten quality differences. If gluten quality does vary, it would be logical to expect that differences would be found in the chemical characteristics of glutens washed from flours of different baking quality. Such differences were apparently discovered by Harris (1937, 1938) in the quantity of gluten protein removed from sodium salicylate dispersion of washed gluten by $MgSO_4$. A significant relationship between quantity of protein removed and loaf volume was found in two series of flours of 30 samples each. One series consisted of durum wheat, while the other was made up of hard red spring wheat. No significant relationship between crude-flour protein content and loaf volume was demonstrated. The standard basic method was used to determine baking quality.

This technique of gluten protein dispersion and fractionation by successive suitable additions of $MgSO_4$ to sodium salicylate dispersions was applied by Harris (1938a, 1938b) to measure the effect of various proteolytic enzymes upon the glutens washed from doughs containing such enzymes. It was found that proteolytic enzymes did affect both rate of gluten dispersion and the relative distribution of the quantity of protein contained in three fractions removed from these

dispersions. One sample of hard red spring wheat flour was used as experimental material in this investigation.

Rupp and Bailey (1937) presented evidence to the effect that gluten from different types of flour is affected to different degrees by the same proteolytic treatment. These workers found that the rate of decrease in the development work (D.W.) of flours, as measured by the farinograph, varied with the quality of the flour used where the same proteolytic treatment was employed for each flour.

In view of these investigations and the results obtained therefrom, it was deemed advisable to apply fractionation methods to glutens washed from doughs made up from samples of flours which had been milled from different classes of wheat and subjected to varying degrees of proteolytic treatment. From the results obtained from such a study, it would be possible to ascertain whether the effect of proteolytic enzyme treatments on the various classes of wheat flours would be reflected in the comparative protein distribution of their gluten fractions.

Experimental Material and Methods

Flours milled from four classes of wheat were used in this study. These wheats represented the hard red spring, hard red winter, soft red winter, and durum classes, and included two commercial and two experimentally milled flours. The papain preparation used in this work was prepared by Merck and Company and had been recently purchased. The pancreatin preparation had likewise been obtained from the same company. The yeast water used as a flour protease activator was prepared according to the method outlined by Jørgenson (1936) and was freshly made immediately before using. Papain was used because of its similarity to flour protease, and pancreatin was included to obtain data from a protease of animal origin.

The papain and pancreatin were dispersed in distilled water at suitable concentrations shortly before incorporation in the dough. After thorough shaking the required quantity of distilled water plus enzyme was added to the water necessary for correct absorption and then incorporated in the dough by a two-minute mix in the Hobart-Swanson. The usual quantities of yeast, sugar, and salt were employed.

The gluten was washed from the doughs immediately after mixing was completed, using a wash solution of pH 6.6 which contained 0.1% sodium phosphate. After the washed gluten had stood a short time under the sodium phosphate solution, 9 grams of wet crude gluten were weighed out, cut into small pieces, and placed in 150 c.c. of 10% sodium salicylate. After standing for several days, with frequent

shaking, the dispersions were centrifuged. The supernatant liquid was now decanted from the residual material in the centrifuge tubes. The dispersed gluten protein was then fractionated according to the procedure outlined by Harris (1938b), employing successive additions of 1.5, 3, and 10 c.c. of concentrated $MgSO_4$ solution per 25 c.c. of dispersion. The volume of $MgSO_4$ solution added to bring down fraction 2 was changed from 4 to 3 c.c. to leave a larger quantity of protein to be recovered in the third fraction.

The moisture determinations were run on 5 grams of wet crude gluten. Heating at approximately 105° C. was continued for 48 hours in a Freas drying oven.

Discussion

The wheat and flour description, crude flour protein, flour ash, and the loaf volumes obtained by the standard basic and malt-phosphate-bromate baking methods are shown in Table I. Substantial differences in protein and gluten content and loaf volume are evident between the hard and the soft wheat samples. The soft winter wheat flour had a low ash content, while the durum straight flour was highest in this constituent. There was no great difference in loaf volume between the two hard wheats despite the higher protein content of the hard red spring. The durum, which is not classed as a bread wheat, yielded relatively low loaf volumes when protein and gluten content are taken into account. Both the spring wheats had exceptionally high dry gluten content in view of their percentages of crude flour protein.

TABLE I

DESCRIPTION AND COMPARATIVE DATA FOR THE FLOURS USED IN THIS STUDY

Sample No.	Description	13.5% moisture basis				Loaf volume	
		Ash	Crude protein N×5.7	Wet crude gluten	Dry gluten	Standard basic	Malt phosphate bromate
		%	%	%	%	*c.c.*	*c.c.*
38–1–56	Hard red spring wheat commercially milled	0.44	13.2	46.1	14.5	577	688
37–11–32	Hard red winter wheat experimentally milled	0.50	12.5	39.4	12.7	591	636
38–4–8	Soft red winter wheat commercially milled	0.28	7.5	20.4	7.1	379	349
37–12–26	Mindum durum wheat experimentally milled	0.87	13.3	44.5	14.2	480	467

In Table II are shown the data obtained from the gluten washed from doughs treated with varying concentrations of papain, as well as doughs without enzymic treatment. No definite trends were established in regard to the gluten data, as marked differences must be found between the gluten contents from various doughs before such differences can be judged significant because of the lack of precision

TABLE II

GLUTEN-MOISTURE AND DRY-GLUTEN CONTENT OF FLOUR AND PROTEIN DISTRIBUTION EXPRESSED AS PERCENT OF TOTAL SOLUBLE PROTEIN IN DISPERSED GLUTENS WASHED FROM DOUGHS TREATED WITH VARIOUS CONCENTRATIONS OF PAPAIN

Flour No.	Treatment	Wet gluten moisture	Dry gluten[1]	Gluten solubility	Fraction			Total protein removed
					1	2	3	
		%	%	*mg. per 100 c.c.*	%	%	%	%
38–1–56 (Hard red spring)	Control, no yeast	67.9	15.0	1462	55.3	29.6	1.2	86.1
	Control, with yeast	67.3	14.5	1448	54.5	32.0	1.6	88.1
	Papain 0.001%	67.6	14.2	1530	46.8	39.8	3.0	89.6
	Papain 0.002%	68.6	14.0	1546	43.8	39.4	3.6	86.8
	Papain 0.004%	68.1	13.8	1502	26.0	52.1	9.2	87.3
	Papain 0.010%	68.1	14.2	1399	19.6	49.9	15.1	84.6
37–11–32 (Hard winter)	Control, no yeast	70.4	12.7	1271	47.8	34.3	5.0	87.1
	Control, with yeast	71.3	13.5	1237	47.4	38.2	2.7	88.3
	Papain 0.001%	71.1	13.8	1294	38.6	40.0	4.2	82.8
	Papain 0.002%	70.4	13.4	1260	30.0	49.9	9.2	89.1
	Papain 0.004%	71.5	14.1	1151	21.8	50.6	14.8	87.2
	Papain 0.010%	69.3	12.6	1420	12.1	43.7	21.7	77.5
38–4–8 (Soft winter)	Control, no yeast	65.1	7.1	1320	40.3	35.2	6.7	82.2
	Control, with yeast	68.9	7.1	1640	45.8	35.1	5.1	86.0
	Papain 0.001%	70.6	7.4	1334	40.2	36.2	8.4	84.8
	Papain 0.002%	67.4	7.8	1431	26.0	44.3	11.9	82.2
	Papain 0.004%	67.5	8.3	1391	23.3	42.6	15.1	81.0
	Papain 0.010%	68.6	6.8	1362	14.5	33.2	26.9	74.6
37–12–26 (Mindum durum)	Control, no yeast	68.1	14.2	1351	37.3	40.7	8.7	86.7
	Control, with yeast	66.9	13.6	1283	42.5	43.3	2.8	88.6
	Papain 0.001%	68.6	13.5	1357	31.8	43.5	10.4	85.7
	Papain 0.002%	66.9	13.6	1448	28.5	45.6	11.3	85.4
	Papain 0.004%	68.2	13.3	1388	35.8	41.7	7.9	85.4
	Papain 0.010%	66.2	8.8	1428	18.2	43.9	17.3	79.4

[1] Calculated to basis of 13.5% flour moisture.

in methods of determining gluten. The low results obtained in the instance of the 0.01% papain treatment of the durum dough was doubtless due to the loss of gluten material during the washing, as this particular dough was difficult to handle and wash. No general trend in the dry-gluten results appeared to be established with papain increments.

Upon examining the first fraction obtained by this method it is seen that the quantity of protein decreases in each class of wheat for increasing concentration of papain. It is also evident that the hard red spring wheat flour dough contained more protein in this fraction following substantial papain treatment than did the hard red winter or soft red winter. The durum results appeared to coincide very closely with the spring-wheat figures at the highest papain dosage employed, but did not resemble the values obtained for the other wheats at lower papain concentrations. The second fraction is increased in general by papain. This fraction varies from 49.9% of control for the hard red spring through 43.7% for the hard winter to 33.2% for the soft winter when 0.01% of papain was used. The durum is practically identical with the hard winter. There thus appears to be a slight trend toward decrease in quantity of protein removed in fraction 2 in going from hard red spring to soft red winter in this concentration of papain in this study. The other papain treatments are not very consistent.

The third fraction appeared to be definitely increased by papain treatment for all the four wheat flours, but this increase varied greatly among the samples. The hard red spring was the lowest, showing a value of 15.1% of control for the highest papain treatment of 0.01%, with the hard winter yielding 21.7% and the soft winter 26.9%, respectively. Fraction 3 accordingly showed a tendency to vary with flour protein and malt-phosphate-bromate loaf volume upon papain treatment in these different classes of wheat. Durum was intermediate between the hard spring and hard winter wheats. The same tendency is also seen when the control-dough results are examined. There is no definite evidence of an increase in the gluten protein fractionated. The solubility of gluten protein in 10% sodium salicylate does not appear to increase with the severity of papain treatment.

In Table III the results obtained by the three concentrations of pancreatin used are shown. An interesting situation is revealed when the quantity of protein removed in fraction 1 is examined. While a general decrease of protein removed in this fraction is shown with an increase in severity of treatment, the degree of decrease from the values yielded by the untreated doughs varies greatly from one wheat class to another, being least in the instance of the durum and greatest for the soft winter wheat. The quantity of protein found in the first fraction following treatment of 0.04% pancreatin ranged from 43.8% of control in the case of the hard red spring dough, to 14.5% for the hard red winter. The durum was second highest and the soft red winter dough next to the lowest. No marked differences are shown in the case of fraction 2, but with the third fraction removed a striking

increase in the quantity of protein thrown out of solution is evident in passing from the hard red spring data through the durum and hard winter to soft winter wheat results. These results correspond with a marked decrease in fraction 1 for the winter wheats. A shift toward the smaller region of particle size appears to be caused by enzymic action, and this effect is more marked in the winter wheat dough gluten dispersions. Some reduction in the quantity of gluten protein fractionated is also visible in these instances.

TABLE III

GLUTEN-MOISTURE AND DRY-GLUTEN CONTENT OF FLOUR AND PROTEIN DISTRIBUTION EXPRESSED AS PERCENT OF TOTAL SOLUBLE PROTEIN IN DISPERSED GLUTENS WASHED FROM DOUGHS TREATED WITH VARIOUS CONCENTRATIONS OF PANCREATIN

Flour No.	Treatment	Wet gluten moisture	Dry gluten[1]	Gluten solubility	Fraction			Total protein removed
					1	2	3	
		%	%	*mg. per 100 c.c.*	%	%	%	%
38–1–56 (Hard red spring)	Control, no yeast	67.9	15.0	1462	55.3	29.6	1.2	86.1
	Control, with yeast	67.3	14.5	1448	54.5	32.0	1.6	88.1
	Pancreatin 0.01%	67.7	14.7	1411	50.1	34.6	1.8	86.5
	Pancreatin 0.02%	67.2	15.6	1342	48.7	34.5	2.0	85.2
	Pancreatin 0.04%	67.4	15.2	1371	43.8	37.2	2.6	83.6
37–11–32 (Hard winter)	Control, no yeast	70.4	12.7	1271	47.8	34.3	5.0	87.1
	Control, with yeast	71.3	13.5	1237	47.4	38.2	2.7	88.3
	Pancreatin 0.01%	72.7	13.1	1191	41.6	40.0	3.9	85.5
	Pancreatin 0.02%	76.7	10.0	1180	15.2	41.4	8.5	65.1
	Pancreatin 0.04%	69.8	13.3	1270	14.5	41.9	9.4	65.8
38–4–8 (Soft winter)	Control, no yeast	65.1	7.1	1320	40.3	35.2	6.7	82.2
	Control, with yeast	68.9	7.1	1640	45.8	35.1	5.1	86.0
	Pancreatin 0.01%	68.3	7.0	1390	52.1	47.2	9.2	108.5
	Pancreatin 0.02%	69.4	8.0	1330	31.9	48.7	11.7	92.3
	Pancreatin 0.04%	66.0	6.6	1340	26.4	40.1	16.7	83.2
37–12–26 (Mindum durum)	Control, no yeast	68.1	14.2	1351	37.3	40.7	8.7	86.7
	Control, with yeast	66.9	13.6	1283	42.5	43.3	2.8	88.6
	Pancreatin 0.01%	69.2	12.6	1294	32.9	46.4	3.2	82.5
	Pancreatin 0.02%	69.1	13.5	1311	39.0	42.1	4.9	86.0
	Pancreatin 0.04%	68.6	13.8	1271	35.7	44.5	6.3	86.5

[1] Calculated to basis of 13.5% flour moisture.

The results obtained when various concentrations of yeast water were incorporated in the doughs are shown in Table IV. The hard winter wheat dough glutens were the highest in gluten moisture. The gluten moisture tended to be raised by yeast water. The crude gluten content was also increased in the majority of cases. The gluten solubility was somewhat depressed by yeast water except in the treat-

ments involving the glutens washed from doughs mixed from durum wheat flours. The first fraction appears to be depressed by the activation of the native flour proteases in the instance of each wheat studied, but this initial effect is not generally increased by heavier doses of yeast water. Harris (1938b) found an increase in the quantity

TABLE IV

GLUTEN-MOISTURE AND DRY-GLUTEN CONTENT OF FLOUR AND PROTEIN DISTRIBUTION EXPRESSED AS PERCENT OF TOTAL SOLUBLE PROTEIN IN DISPERSED GLUTENS WASHED FROM DOUGHS TREATED WITH VARIOUS CONCENTRATIONS OF YEAST WATER

Flour No.	Treatment	Wet gluten moisture	Dry gluten[1]	Gluten solubility	Fraction			Total protein removed
					1	2	3	
		%	%	*mg. per 100 c.c.*	%	%	%	%
38–1–56 (Hard red spring)	Control, no yeast	67.9	15.0	1462	55.3	29.6	1.2	86.1
	Control, with yeast	67.3	14.5	1448	54.5	32.0	1.6	88.1
	Yeast water 10 c.c.	71.7	14.8	1243	40.7	46.6	2.2	89.5
	Yeast water 20 c.c.	71.3	15.2	1248	35.8	47.7	2.4	85.9
	Yeast water 25 c.c.	71.7	15.2	1214	40.8	42.7	1.3	84.8
37–11–32 (Hard winter)	Control, no yeast	70.4	12.7	1271	47.8	34.3	5.0	87.1
	Control, with yeast	71.3	13.5	1237	47.4	38.2	2.7	88.3
	Yeast water 10 c.c.	72.4	14.3	1151	40.8	44.4	3.3	88.5
	Yeast water 20 c.c.	73.3	13.5	1106	40.6	45.7	3.7	90.0
	Yeast water 25 c.c.	72.8	14.1	1140	36.0	44.0	6.0	86.0
38–4–8 (Soft winter)	Control, no yeast	65.1	7.1	1320	40.3	35.2	6.7	82.2
	Control, with yeast	68.9	7.1	1640	45.8	35.1	5.1	86.0
	Yeast water 10 c.c.	69.2	7.3	1340	43.7	38.8	6.0	88.5
	Yeast water 20 c.c.	68.7	7.3	1351	38.3	41.2	7.5	87.0
	Yeast water 25 c.c.	57.0	10.7	1288	37.0	42.2	7.1	86.3
37–12–26 (Mindum durum)	Control, no yeast	68.1	14.2	1351	37.3	40.7	8.7	86.7
	Control, with yeast	66.9	13.6	1283	42.5	43.3	2.8	88.6
	Yeast water 10 c.c.	67.5	14.3	1322	34.7	45.0	8.5	88.2
	Yeast water 20 c.c.	67.4	8.8	1419	33.4	43.1	8.0	84.5
	Yeast water 25 c.c.	70.6	12.7	1328	35.4	43.6	8.4	87.4

[1] Calculated to basis of 13.5% flour moisture.

of protein removed as fraction 1 following treatment with yeast water when using hard red spring flour milled from the 1936 wheat crop as investigational material. It was therefore postulated in the instance of this research that activated flour protease appeared to exert a coagulating influence upon flour gluten protein, and in this way differed from papain. No increase in the depressive effect was noted in the present instance when larger quantities of the activating liquid were added, however, and in this respect the results agree with the former conclusions of the author. It is possible that increasing the con-

centration of activator does not increase the activating effect, and this explanation may account for the failure of fraction 1 to decrease with increasing severity of yeast-water treatment, rather than to differences in the action of flour protease and papain. It does not seem probable that these four flours would contain equal quantities of protease, and therefore the lack of decrease in fraction 1 with increase in severity of treatment cannot be attributed to a lack of the enzyme content necessary to further affect the gluten. The other two gluten protein fractions do not appear to be affected to any marked degree by yeast water although a slight tendency toward increase in quantity of protein removed in fraction 3 is seen when progressively comparing the results from the hard red spring wheat with the hard winter and soft winter wheats.

The general effect of proteolytic enzymes in decreasing the quantity of gluten protein in fraction 1 was shown by all four flours for the three enzymes employed. The hard red spring wheat flour gluten had the largest proportion of protein removed in fraction 1, but this fraction was reduced by proteolytic action to a greater extent in this instance than in the other wheat flour glutens. The soft winter wheat glutens were the least affected in the class of bread wheats, while the winter wheat was intermediate in this respect. The durum showed the smallest difference between the dough without yeast or enzyme and the dough containing the highest dosage of enzyme with yeast. These relationships were true for the papain and pancreatin doughs, but were not true when yeast water was used as an activating agent for the flour protease. When pancreatin was used the hard red spring wheat glutens were not affected as markedly as were the hard winter, while the durum was least affected. The change in the relative ranking of the spring wheat when treated by pancreatin instead of papain was probably due to some difference in the effect of the two enzymes upon the flour gluten. The highest dosage of pancreatin used did not have as much effect as the 0.01% treatment of papain, and the spring wheat gluten may have been more resistant to its action than were the hard winter wheat flour glutens. This explanation does not seem very probable, however, in view of the results yielded by the soft winter wheat gluten, which showed less effect with pancreatin than with papain.

The hard red winter wheat sample showed a tendency to have the smallest quantity of gluten protein removed as fraction 1 following the addition of proteolytic enzymes to the dough. The soft red winter wheat, on the other hand, had the largest proportion of protein removed in fraction 3 as compared with the other samples. There appeared to be a distinct trend toward an increase in the third fraction

in going through the data from hard red spring to hard red winter, finishing with the soft winter. The durum samples yielded results nearest the hard red spring wheat. This trend applied to the papain and pancreatin treatments, and was not apparent when the data obtained by the yeast-water treatments was examined.

Fraction 2 appeared to decrease in proportion in going from hard red spring to soft red winter when the papain treatments were considered, as shown in Table II, while the hard red winter was intermediate in this respect.

It would seem that there is a difference in the aggregation of the gluten protein complex among the various classes of wheat examined in this study. Fraction 1 tends to decrease from the hard red spring wheat doughs to the winter wheat, both in the instance of the doughs treated with proteolytic enzymes and the untreated doughs. Fraction 2 also tends to change in much the same manner. Fraction 3 is increased as one goes through the data from the spring wheats to the soft winter. This change is also apparent upon proteolytic treatment. These results, it seems to the authors, may possibly be explained by the existence of smaller gluten particles in the case of the winter wheat as compared with the spring wheat. It is, however, realized that too rigid generalizations cannot be made from results obtained from an examination of only one sample of each of the classes of wheat included in this research.

Summary and Conclusions

Four flours milled from hard red spring, hard red winter, soft red winter, and durum wheat were analyzed for ash, total protein, and dry crude gluten. These flours were also baked by two methods: the basic standard with 5% of sucrose and the malt-phosphate-bromate, which included 0.3% of 60° Lintner malt, 0.1% of ammonium phosphate, and 0.001% of potassium bromate in addition to the basic ingredients.

These flours were mixed into doughs in the customary manner with the exception that appropriate concentrations of papain, pancreatin, and yeast water were incorporated in the dough mix in all except the control doughs. The gluten was washed from these doughs immediately after mixing, and the percentages of gluten moisture and dry crude gluten determined. A portion of the wet crude gluten was dispersed in 10% sodium salicylate solution and the final concentration of dispersed gluten protein determined. The dispersed protein was then fractionally precipitated by successive additions of $MgSO_4$ solution and the quantity of protein determined in each fraction.

The results obtained showed that proteolytic enzymes affect the relative distribution of the protein fractions in different classes of wheat

flour in the same general manner. The first fraction was progressively reduced in quantity as the concentration of enzyme increased. This effect is then reflected in a decrease in the second fraction as the severity of the treatment is increased. The quantity of protein removed in fraction 3, on the other hand, is augmented by this treatment.

The effect of papain and pancreatin upon the proportion of gluten protein contained in fraction 1 differs somewhat among the four samples of wheat flour included in this study. Hard red spring wheat gluten when dispersed in sodium salicylate has apparently the largest quantity of protein removed in fraction 1 following the addition of substantial quantities of enzyme to the doughs from which these glutens were initially washed. Hard winter wheat glutens have the least removed, although the soft winter results were quite close to the hard winter. The durum wheat gluten approached closest to the hard red spring in quantity of gluten in this fraction.

Fraction 2 is not greatly affected by the action of enzymes in the concentration employed in this work. Fraction 3 is increased in all the gluten dispersions by increasing the concentration of enzyme. This effect was not apparent, however, when yeast water was employed. This fraction increases in a striking manner when the results from the hard red spring wheat doughs are progressively compared to the hard red winter and the soft red winter values. The increase in fraction 3 for the durum flour dough glutens is second lowest, being next in order to the spring wheat. This change of protein quantity thrown down as fraction 3 appears to follow roughly the order of the bread wheat flours in protein content and malt-phosphate-bromate loaf volume. It may be that the effect of papain and pancreatin in concentrations employed in this study is to decrease the size of the gluten particle to a larger extent in the instance of the winter wheat than in the spring wheat. This would entail less protein being thrown down in fraction 1, which presumably contains the larger-size protein particles, than in the case of the winter wheat, with an increase in fraction 3 where a substantial portion of the small particles are removed. These shifts in the relative proportions or quantity of protein removed are not quantitative, however, and therefore can only be regarded as indicators or trends, and are not conclusive. It was previously found by one of the authors that durum wheat contained a lower proportion of fraction 1 and a larger proportion of fraction 3 than did hard red spring wheat of the 1936 crop. This is in accord with the present findings. A lower protein solubility was also postulated for the durum in that instance.

Acknowledgments

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MAINTAINING A UNIFORM TEMPERATURE IN AN EXPERIMENTAL BAKING OVEN

K. F. FINNEY and M. A. BARMORE

Division of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Dept. of Agriculture [1]

(Received for publication October 28, 1938)

The maintenance of a uniform temperature and the reduction of heat loss in experimental baking ovens has been the subject of much attention by cereal chemists. The loss of heat is a factor of considerable importance, because the greater the loss the more difficult it is to maintain a uniform temperature in the oven and in the surrounding room. The rise in room temperature is particularly serious in areas of high summer temperatures and especially so if the baking laboratory is not air-conditioned. These considerations led to a study of heat losses in an experimental baking oven at this laboratory, and also to certain oven alterations that are believed to be desirable.

The inside dimensions of the oven are $34 \times 34 \times 26$ inches high. The door opening is $12\frac{1}{2} \times 18$ inches. A shelf rotating at 2 r.p.m. is suspended above a refractory hearth about one inch thick. Top and bottom heat is supplied by elements of 5 kw. total capacity. The removable front and a metal-lined door necessarily result in considerable metal connection between the inside and outside oven walls and in consequence the loss of heat is greatest from the front wall. The heat

[1] Hard Winter Wheat Quality Laboratory, in cooperation with the Kansas Agricultural Experiment Station, Manhattan, Kans.

losses consist of direct radiation and that occasioned by the frequent opening of the door. These two losses were found to be approximately equal. It was observed that opening the door for 10 seconds caused the temperature inside the oven to drop 40° F. and that 1½ minutes were required to restore the temperature.

In order to reduce the heat losses and to maintain a more uniform temperature the front and adjoining corners were insulated, the size of the door opening was reduced, and partitions on the rotor and a stationary canopy inside the door were installed. These modifications are illustrated in Figure 1. The insulation is about 1½ inches thick and

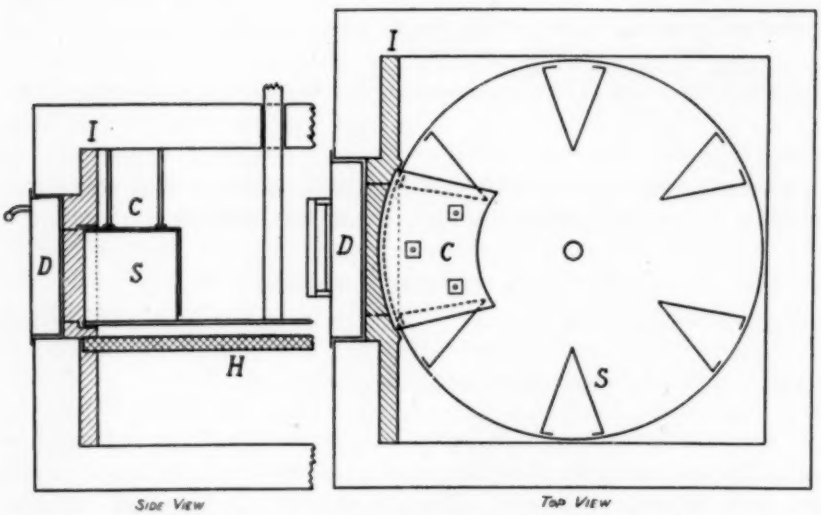

Fig. 1. Modified baking oven showing canopy (*C*), partitions (*S*), door (*D*), added insulation (*I*), and hearth (*H*).

consists of a shredded asbestos mixture containing some binder. It handles much like mud when wet. It has a low density when dry and sticks to the metal satisfactorily. The size of the door opening was reduced to $8 \times 11\frac{1}{2}$ inches. The insulation produced a noticeable difference in the temperature of the outside walls of the oven and tests showed that the radiation losses were reduced by at least 25%.

The most important alterations were on the rotating shelf and these were adapted from equipment in several Canadian laboratories. In those ovens the rotating shelf contains a series of small, completely inclosed, identical sections, each large enough for a single loaf—essentially a series of ovens within an oven. The width of a section is the same as that of the door opening so that only one section is exposed when the door is opened. This arrangement reduces the heat loss con-

siderably but might be less desirable from the standpoint of experimental baking than the single large baking space.

After consideration of several possible plans to block off the major part of the oven when the door was open and yet allow all loaves to be baked in one large compartment, the device illustrated in Figure 1 was adopted. This consists of vertical side walls (S) fastened to the rotating shelf in such a way that they successively come under a stationary canopy (C) just inside the door. The canopy is suspended from the top of the oven and temporarily forms the top and back of each cell successively. When not under the canopy the loaves are separated from each other only by side walls and are baked under substantially uniform conditions. When the side walls of a section come into the position shown in the top view of Figure 1, the opening of the door exposes only a relatively small space to the exchange of air from the baking laboratory. The canopy and partitions were constructed of 14-gauge black iron. The canopy is attached to the top of the oven so that there is about $\frac{3}{8}$ inch of clearance above the rotating shelf, which is reduced to about $\frac{1}{8}$ inch or less when the oven is hot.

With this installation, opening the door for 10 seconds with the rotating shelf stopped, closing the door, and then starting the rotor caused an oven temperature drop of only 5° F., which was restored in a half minute. The heat lost to the room by opening the door in this manner once every three minutes did not cause any detectable increase in the power consumed by the oven. Stopping the rotating shelf at the proper position is easily effected by watching an indicator installed on the top of the oven which shows the shelf position. Tests have shown the variability in loaf volume due to position in the baking schedule to be lower than previously, and this can be at least partly attributed to the changes in oven design.

It was at first thought that the hearth supplied with the oven was of no appreciable advantage and should be removed, as many cereal chemists have done. However, it was found that the change in oven temperature from an empty to a full load was 6° F. with the hearth in place and 11° F. after the hearth was removed. Although the drop with the hearth in place was comparatively large for the first loaf, the additional drop from this point to a full load was only 2° F. as compared with 6° F. with the hearth out. Thus each test indicated that more uniform temperatures during the baking period could be maintained with the hearth in place.

Summary

Insulation of an experimental baking oven effected a material reduction in heat lost by radiation.

The installation on the rotating shelf of a series of side walls which moved successively under a stationary canopy immediately inside the door reduced the heat loss still further and markedly improved the uniformity of temperature within the oven.

The temperature during the entire baking period from the first loaf to full oven load was maintained more uniformly with the refractory hearth installed than without it.

A SIMPLE LABORATORY SHAKING MACHINE

MAX C. MARKLEY

Cargill, Inc., Minneapolis, Minnesota

(Received for publication September 19, 1938)

The new Zeleny method for the determination of the fat-acidity of corn [1] calls for the use of a shaking machine during the extraction of the fatty acids. Not many of the cereal laboratories are equipped with a shaking machine of sufficient capacity to handle any appreciable number of such tests at one time. No standard machine for shaking a large number of glass-stoppered bottles at one time could be found in an examination of the available laboratory supply catalogs. A Kahn-test instrument could be adapted to this purpose by constructing special bottle racks to replace the test-tube racks regularly supplied, but this would mean an investment of a hundred dollars or more.

A shaking machine of ample capacity can be constructed, without the utilization of special castings or costly machine work, from about $20 worth of parts, including the motor, and not more than 16 hours of labor. Only hand tools are required though a power drill reduces the labor. This instrument can be built from angle iron and home-workshop power-transmission equipment. The bottle rack should be made of wood, preferably a rather soft and straight-grained wood such as redwood. The machine with a rack for holding 24 bottles is shown in Figure 1.

The base for the machine was built of $1'' \times 1'' \times \frac{1}{8}''$ angle iron and measured 46″ long by 6″ wide. Either rivets or welds can be used in the framing. To this frame were bolted 8 line-shaft hangers with ½″ bronze bearings as shown in Figure 2. The sliding carriage was made of the 1″ angle iron and was $17\frac{1}{2}'' \times 6''$. It was carried on two 24″ lengths of ½″ steel shafting, spaced 5″ from center to center. The shafts were bolted to the carriage and slide freely in the four central bearings attached to the base.

[1] Lawrence Zeleny. Paper read at the 1938 convention.

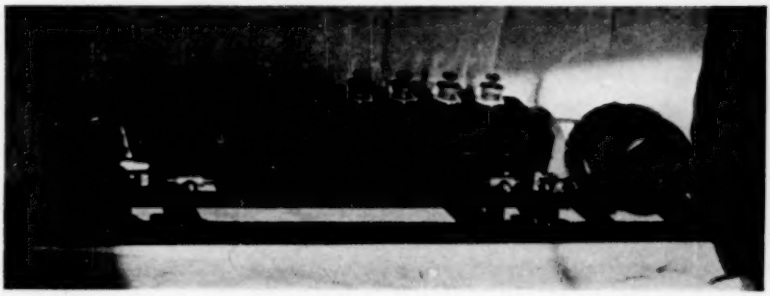

Fig. 1. Shaking machine fitted with rack for 24 bottles.

The crank was made from a solid steel pulley of ¾″ face and 1¾″ diameter. The crank-spindle was made by bushing a stove bolt which was passed through the pulley ⅝″ from the center. This gave a 1¼″

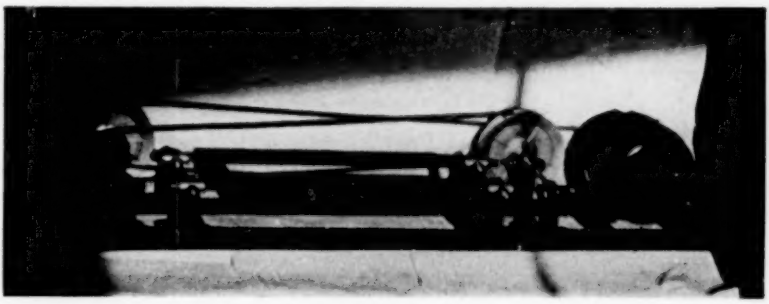

Fig. 2. Chassis of shaking machine showing crank assembly and carriage bearings.

throw to the pitman rod, which was made of ¾″ × ¾″ × ⅛″ angle iron with the ends filled with bearing metal. The pitman rod was quite long, 19½″ between centers, which insured smooth action. The crank-shaft was fitted with a 6½″ pulley which was driven from a 2½″ pulley on the counter-shaft. For a 1750 r.p.m. motor a 1½″ pulley was found to be satisfactory with a 6½″ pulley on the counter-shaft. With the long distances between centers the belt tension was low and round belts were satisfactory. The motor need not be over ⅙ horsepower.

THE RELATION OF MECHANICAL STIRRING TO SPONGE DOUGHS

J. C. Baker and M. D. Mize

Wallace & Tiernan Laboratories, Newark, N. J.

(Read at the Annual Meeting, May 1938)

The authors have shown in a previous paper that the action of bromate in a dough is promoted by mechanical stirring. Upon observing a trough of dough during the sponge period it was noted that the evolution of gas and the extension of the dough by the bubbles kept the dough in a slight but continuous motion. In view of the effect of mechanical working of doughs upon bromate action, this motion in the sponge suggested that one of the functions of the sponge was the stimulation of the bromate by motion. Bearing in mind that the action of bromate can be accelerated mechanically, one might be able to substitute mechanical stirring for the fermenting sponge period in bread making and obtain similar results. This hypothesis was tested and is illustrated in the following table.

TABLE I

Baking Results

Kansas patent—ash 0.40%, protein 13.0%, moisture basis 15%

Mixing time [1]	Type of fermentation	Volume	Texture	Maturity
min.		*c.c.*		
3	2½ hrs. straight dough—no bromate	2260	80	Green
3	2½ hrs. straight dough plus 20 p.p.m. bromate	2540	95	Mature
3	4 hrs. 60%–40% sponge—no bromate	2480	86	Green
3	4 hrs. 60%–40% sponge plus 20 p.p.m. bromate	2730	97	Mature
3	4 hrs. 60%–40% sponge plus 20 p.p.m. bromate, no yeast in sponge—yeast added during dough-up	2520	80	Green
30	Mechanical 60%–40% sponge—no bromate, 20-minute fermentation	2340	88	Green
30	Mechanical 60%–40% sponge plus 20 p.p.m. bromate 20-minute fermentation	2760	97	Mature

[1] A Swanson mixer running at 52 r.p.m. was used.

The results without and with bromate in a straight dough are first given, followed by the results without and with bromate in a 4-hour sponge dough, showing the characteristic improvement in both of the sponge doughs, but the noticeably greater improvement produced by the bromate. The next loaf is a 4-hour sponge containing bromate in which the yeast was omitted, but subsequently added during the

dough-up. It is to be noted in this case that during the yeastless sponge stage where no motion occurs the resulting bread has practically the same volume as the 4-hour sponge without bromate and has the characteristic texture and quality of bread from unoxidized doughs, though the bromate had been present throughout the entire sponge and proofing period. In the absence of both yeast fermentation and mechanical motion, bromate has little apparent action.

The next two loaves indicated in Table I show the substitution of a 30-minute mechanical-mixing period for the 4-hour sponge period. In all other respects the handling of the doughs was the same and they were allowed the regular 20-minute resting period after doughing-up. It is to be noted where no bromate was used that the results were very similar to those obtained in the 4-hour sponge without bromate. Also where bromate was used, the results were very similar to those obtained in the 4-hour sponge with bromate. These results seem to confirm the theory that one of the chief functions of the 4-hour sponge is the activation of the bromate by the motion which the fermentation produces.

SOME OBSERVATIONS REGARDING THE FLAVOR OF BREAD

J. C. BAKER and M. D. MIZE

Wallace & Tiernan Laboratories, Newark, N. J.

(Read at the Annual Meeting, May 1938)

In connection with some of the researches being conducted in this laboratory, a method of baking crustless bread was developed. The dough was heated by being made the resistance between electrodes carrying alternating current. All portions of the dough were subjected to approximately the same temperature at the same time. No crust was formed. The bread was characterized by a slightly milder flavor, distinctly yeasty in character, suggestive of the odor of yeast fermentation—that is, slightly alcoholic but flavored with the other by-products of yeast fermentation such as diacetyl. The keeping quality of the flavor was superior to that of ordinary oven-baked bread. This crustless bread shows at the end of one, two, or three days of storage at room temperature very slight changes in the flavor characteristics, the main difference observed being a slight disappearance of flavor.

In contrast to this, bread freshly baked in the ordinary commercial way from the same dough exhibits a stronger flavor, rich in the odor of carmelization and the effects of high temperature on the crust. This odor is present not only in the crust but in the interior crumb of the bread. In other words, if the interior of the loaf is completely

removed from the crust and its odor observed separately, it still carries the odor characterized by the crust, suggesting that the odors of the crust have been carried to the interior of the loaf.

Bread baked in the ordinary manner and also the separated interior portion of this bread develops upon storage the usual flavors which in the trade are called "stale."

A study was made to find what causes this flavor to develop in crust bread. A bread was made without shortening. A second bread was made in which ordinary shortening was used. A third bread was made in which a bland mineral oil was substituted for the shortening. A fourth bread in which ordinary shortening was used was thoroughly sprayed with mineral oil before panning and further sprayed before going to the oven.

The characteristics of these loaves, with an electric-baked crustless loaf containing shortening used as a standard, were as follows: The bread baked with mineral-oil shortening had a flavor nearly as mild as the crustless bread standard. The bread baked with ordinary shortening and sprayed with mineral oil had a flavor stronger than the standard but intermediate between mineral-oil shortening and ordinary shortening. The bread baked with no shortening had a flavor stronger than the standard but intermediate between the mineral-oil shortening and the ordinary shortening.

All observations on these loaves were made by six trained observers, all of whom are laboratory technicians familiar with cereal problems and familiar with bread flavors. All conclusions stated here are only those in which all observers were in agreement. In other words, the differences in the odor were so distinctly noticeable and so easily characterized that there was no disagreement among the observers as to these conclusions.

Upon storage the following observations were made: The bread with mineral-oil shortening retained during storage a flavor similar to the electric baked crustless loaf but with slightly more deterioration of flavor. The bread with no shortening and the bread with ordinary shortening but sprayed with mineral oil showed some deterioration of flavor and more evidence of flavor staling with age. The bread containing ordinary shortening and no mineral oil or spray gave the usual deterioration and developed the usual flavor staleness with age more definitely than any of the other loaves.

The following conclusions are evident from this work:

The flavor of bread is due to the flavor of the ingredients plus products developed by the yeast and to products developed by heat reactions in the crust.

The flavor products developed by the yeast and the ingredient flavor do not independently undergo appreciable deterioration with age and will not alone produce the stale flavor ordinarily found in old bread.

The flavor products developed in the crust during baking reach the interior of the loaf and are involved in the changes that occur in the flavor of the bread during aging and staling. These effects are intensified by the presence of shortening in the crust.

ANNUAL REPORT OF TREASURER

OSCAR SKOVHOLT

January 1, 1939

The Association has continued to enjoy a healthy growth with a considerable net gain in both active and corporation members to a new high total of 600. The addition of 64 new members is a tribute to the activities of the Membership Committee.

The Executive Committee has authorized a transfer of $200 per year (beginning July 1, 1938) from General Association funds for the support of *Cereal Chemistry*, to aid in securing more assistance for the management of the publication. This committee also decided that $150 a year should be transferred annually to the Decennial Index fund, equally provided by *Cereal Chemistry* and the Association. The 1937 transfer eliminated the deficit in this fund and a surplus for the future indexes is now beginning to accrue.

An unprecedented surplus has resulted from the year's activities. Most of this surplus was earned by *Cereal Chemistry* due to increased receipts and reduced expenditures. The General Association profit is also substantial when considering that some expenses that are not annual were incurred. These include costs of the Osborne Medal Award and some expenses incidental to the transfer of the management of *Cereal Chemistry*. Reduced regular expenditures are responsible for the substantial surplus in the Association fund. All officers spent less than in previous recent years due to reduced expenditures for stenographic assistance. Since the time required to handle the details of all offices is increasing, this implies more work by officers and possibly more assistance by stenographers while on duty for the employers of the officials. It is believed that the time is at hand when more of the official duties should be delegated to paid employees of the Association.

The Secretary has placed an addressograph in working order and this expense plus certain addressograph services to other officers and committee members has been borne by that office. This undertaking requires considerable attention in view of membership and address changes, but one such address list may profitably be maintained by some Association official or employee.

On May 22d, the Executive Committee voted to transfer the remaining funds in the Experimental Laboratory Baking Fund to the Association General Fund. This transfer is shown in the statement under "Distribution of Net Assets."

The assets of the bankrupt Kansas City Building and Loan Company have been acquired by the North American Saving and Loan Association of Missouri, located in Kansas City. The Association assets in this Company now consist of $400 of Class A stock with accumulated interest of $18.26 plus $1600 of Class B shares of undetermined value. The assets securing these Class B shares are being liquidated as rapidly as practicable, and when sufficient funds accumulate, they will be converted to Class A stock, which bears a 3½ per cent rate of interest at present.

There are on hand 140 copies of *Cereal Laboratory Methods*. During the year, 78 copies were sold, and the rate of sale is decreasing slowly. A revised edition may be desirable in 1941. A substantial surplus has accumulated to finance a new edition.

DETAILED MEMBERSHIP STATEMENT DECEMBER 31, 1938

	Total	Active	Corp.	Hon.
Membership December 31, 1937	564	515	47	2
New members added during 1938	64	57	7	—
Members reinstated during 1938	6	6	—	—
Members resigned and suspended for non-payment of dues during 1938	*30*	*29*	*1*	—
Members lost by death	*4*	*4*	—	—
Members in good standing December 31, 1938	600	545	53	2
Net increase in membership during 1938	36	30	6	—

PROFIT AND LOSS STATEMENT

January 1 to December 31, 1938

RECEIPTS			
Cereal Chemistry			
Membership Dues			
Active	$1,914.50		
Corporation	530.00		
Subscriptions, reprints, back issues, and advertising	6,234.78		
1938 Accounts Receivable	333.25		
Net 1938		$9,012.53	
Interest on Invested Funds		57.59	
Miscellaneous Income		3.50	
Appropriated by Association		100.00	
Total Net Receipts 1938			$ 9,173.62
Association			
Membership Dues		1,907.50	
Application Fees		171.00	
Interest on Invested Funds		53.85	
Miscellaneous Income		4.71	
Total Net Receipts 1938			2,137.06
Cereal Laboratory Methods Sales during 1938		215.20	
Interest on Invested Funds		16.80	
Total Net Receipts 1938			232.00
Decennial Index			
Received from *Cereal Chemistry*		75.00	
Received from Association		75.00	
Total Net Receipts 1938			150.00
TOTAL RECEIPTS OF ALL ACCOUNTS 1938			$11,692.68
DISBURSEMENTS			
Cereal Chemistry			
Cost of printing Journal and Reprints	$6,017.90		
Less: 1937 account paid 1938	*63.83*		
Net Cost of Printing		$5,954.07	
Cost of Editors and Miscellaneous Services	1,809.32		
1938 Accounts Payable	6.34		
Net Cost of Editing		1,815.66	
Decennial Index—*Cereal Chemistry* Assessment		75.00	
Net Disbursements 1938		7,844.73	
Surplus 1938			$ 1,328.89

Association			
Expenses of President's and Vice President's Offices and News Letter	257.12		
Expenses of Secretary's Office	132.67		
Expenses of Treasurer's Office	127.36		
Committee Expenses	11.99		
Convention Ads in *Cereal Chemistry*	20.00		
Cincinnati Convention Report	331.06		
Osborne Medal Award	317.55		
Expenses of Managing Editor's trip to Washington	91.25		
Appropriated to *Cereal Chemistry*	100.00		
Decennial Index—Association's Assessment	75.00		
Miscellaneous Expense	27.93		
Net Disbursements 1938		1,491.93	
Surplus 1938			645.13
Cereal Laboratory Methods			
Mailing Expenses		18.13	
Surplus 1938			213.87
Decennial Index			
Surplus 1938			150.00
TOTAL DISBURSEMENTS OF ALL ACCOUNTS			$ 9,354.79

DISTRIBUTION OF NET ASSETS

Cereal Chemistry Assets 1937	$3,981.57	
Surplus 1938	1,328.89	
Assets Dec. 31, 1938		$ 5,310.46
Association Assets 1937	3,818.54	
Transfer from Experimental Laboratory Baking Fund	80.95	
Surplus 1938	645.13	
Assets December 31, 1938		4,544.62
Convention Reserve Fund 1937	1,000.00	
Assets December 31, 1938		1,000.00
Cereal Laboratory Methods Fund 1937	1,070.29	
Surplus 1938	213.87	
Assets December 31, 1938		1,284.16
Decennial Index Fund 1937	None	
Surplus 1938	150.00	
Assets December 31, 1938		150.00
Experimental Laboratory Baking Fund 1937	80.95	
Deficit (by transfer) 1938	*80.95*	
Assets December 31, 1938		None
TOTAL ASSETS DECEMBER 31, 1938		$12,289.24

FINANCIAL STATEMENT DECEMBER 31, 1938

ASSETS	
Manufacturers Trust Company—Checking Account	$ 5,372.89
Petty Cash Fund—Lincoln, Neb.	199.18
Emigrant Industrial Savings Bank—New York	851.24
Franklin Savings Bank—New York	522.07
Harris Trust Company—Chicago	2,016.95
Building & Loan Stock—Kansas City[1]	1,000.00
U. S. Treasury Bonds	2,000.00
1938 Income Receivable	333.25
GROSS ASSETS	$12,295.58

[1] Carried on books at same value as authorized in 1936, although now consisting of $400 of Class A interest-bearing shares in North American Savings and Loan Association of Missouri, with accumulated interest of $18.26 plus $1600 of Class B certificates of undetermined value.

GROSS ASSETS	$12,295.58
LIABILITIES	
1938 Accounts Payable	6.34
NET ASSETS	$12,289.24

REPORT OF THE AUDITING COMMITTEES

We have examined the books and the report of the Treasurer for the year 1938 and to the best of our knowledge and belief, these are a true and accurate account of the receipts and expenditures of the American Association of Cereal Chemists.

H. K. PARKER, *Chairman*
W. E. STOKES
CHAS. A. GLABAU

We have examined the books of the Managing Editor of CEREAL CHEMISTRY for the calendar year 1938 and find the same to be correct to the best of our knowledge.

H. H. JOHNSON, *Chairman*
A. A. ANDRE

BOOK REVIEW

Outlines of Biochemistry. The Organic Chemistry and the Physicochemical Reactions of Biologically Important Compounds and Systems. By Ross Aiken Gortner, Professor of Agricultural Biochemistry in the University of Minnesota, and Chief of the Division of Agricultural Biochemistry, University of Minnesota and the Minnesota Agricultural Experiment Station. John Wiley and Sons, Inc. New York. Chapman and Hall, Limited, London. 1017 pages. Price $6.00.

The appearance of the second edition of *Outlines of Biochemistry*, nine years after the first (for an excellent review of which see Cereal Chemistry, **6**: 541), is enthusiastically welcomed by biochemical workers, teachers and students, whether in general or in highly specialized fields. All who have appreciated the nature, the quality, and the scope of the first edition will be impressed with the magnitude of the task of revision in the light of biochemical progress made during the past ten years, with particular reference to enzymes, hormones, vitamins, proteins, etc. As stated in the author's preface, "the present edition represents an extensive revision and in a large part the complete re-writing of the text. In addition, three new chapters have been added dealing, respectively, with oxidation-reduction, the flavins, and the hormones. A section on lignin has also been added." The chapter on vitamins is again contributed by Dr. L. S. Palmer.

As was true of the first edition, the book admirably serves the interests of both plant and animal biochemistry. The author's chief concern is with fundamental biochemical substances, properties, and processes *as such*, with special emphasis on colloid phenomena. The thorough discussion of colloids and colloid properties is justified on the basis that "all of the reactions and interactions which we call life take place in a colloid system."

Written in a style that characteristically reflects the author's forceful personality and enthusiasm, the book is unexcelled in its capacity for stimulating and holding the interest of the student. For illustrations and examples Dr. Gortner draws freely upon his large fund of personal experience and upon the experiences of his students and associates, both past and present. Numerous and well chosen references to the works of others are accompanied by full and complete literature citations. Although the current edition contains 200 pages more than the first one, the size of the book is substantially the same, and this without any sacrifice in quality of paper or printing.

The author has for many years maintained an active and a special interest in the basic constituents and colloidal properties of cereals, and his book contains numerous references to these and related matters. Gortner has been and remains a powerful influence in the lives and training of many cereal chemists, and it is safe to say that no wide-awake cereal technologist will want to be without access to a copy of *Outlines of Biochemistry*.

M. J. BLISH